COMBUSTION

Vol. 5, No. 8 FEBRUARY, 1934 25c a copy

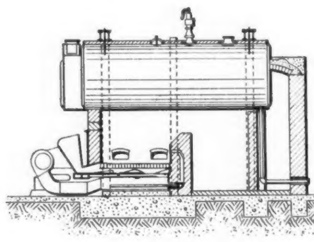
Kips Bay Station, New York Steam Corporation. (See page 22)

Making Garbage Light City Streets

Air Leakage in Steam Generating Units

Small Boiler Units as well as Large

The relative size of these two units is accurately shown, both drawings having been made on the same scale. The extreme range of Combustion Engineering installations of steam generating equipment is manifested by the fact that there are in operation today C-E boilers which have ten times the capacity of the *larger* boiler here illustrated.

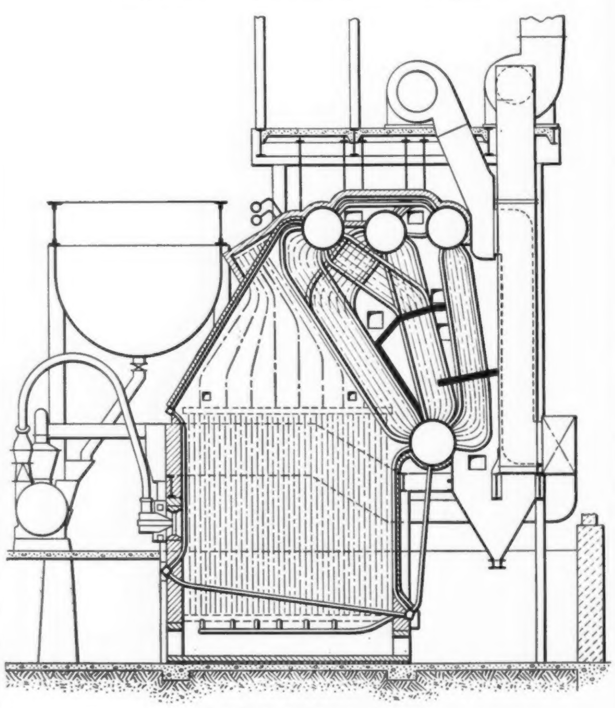


C-E CONTRACT

includes boiler and firing equipment as follows:
C-E H.R.T. Boiler
1500 sq. ft. of heating surface
Type E Stoker
(Electric drive type)

OPERATING DETAILS

CAPACITY, maximum continuous: 7200 lb. of steam per hour. (equivalent to 150 per cent of boiler rating.)
PRESSURE: 150 lb. per square inch
EFFICIENCY, Boiler and Furnace: 72 per cent.



C-E CONTRACT

covers complete boiler, firing and auxiliary equipment, as follows:
C-E Multiple Circulation Boiler 15,000 sq. ft. of heating surface
C-E Water Cooled Furnace
C-E Air Preheater
C-E Direct Fired System
for pulverized fuel firing comprising four Type R Burners and two Raymond Impact Mills each having a capacity of 10,000 lb. per hr.
Contract also includes
superheater, soot blowers and forced and induced draft fans

OPERATING DETAILS

CAPACITY, maximum continuous: 150,000 lb. of steam per hr.
OPERATING PRESSURE: 410 lb. per sq. in.
EFFICIENCY, Boiler and Furnace: 87 per cent.

Every C-E job—large or small—comprises equipment and overall design which extensive and diversified experience indicate to be best suited to the conditions.

The two drawings here reproduced show boiler units covered by two new contracts both of which were received by us on the same day. One has a capacity of 7200 lb. of steam per hr., the other 150,000 lb. per hr. Widely different in design and equipment detail, these two installations typify the range and diversity of Combustion Engineering work.

Small manufacturing plants, as well as the largest industrials and utilities, recognize the precise suitability of C-E equipment for their respective needs.

They know the value of dealing with an organization accustomed to developing designs for the most varied requirements, and which builds a line of equipment that provides complete freedom of choice.

They know, too, that every C-E job—large or small—reflects this Company's purpose: to make every C-E installation measure up to the requirements of a reference plant; an installation that will, through many years of operation, exemplify the practical advantages of Combustion Engineering's diversified experience with fuels and their use for the purpose of steam production.

COMBUSTION ENGINEERING COMPANY · INC.

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COMBUSTION

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DEPARTMENTS

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EDITORIAL

Power from Garbage At Detroit

GARBAGE and city refuse have seldom been regarded as a profitable source of power generation. While incinerators are quite generally displacing other means of disposal, their location is determined by reference to garbage collection which may or may not be favorable to steam generation. Moreover, the high moisture content of the garbage renders its heating value low in the "as received" state. Inasmuch as partial drying by stack gases is productive of obnoxious odors, the usual practice is to burn the refuse and garbage as received, in which the high furnace temperature assures complete combustion.

In view of this the experiments now being conducted at the Mistersky Municipal Power Station in Detroit, as described elsewhere in this issue, are of particular interest. At small expense for slight furnace modifications, garbage and pulverized coal are being burned simultaneously. Partial dehydration by mechanical means obviates the odors incident to flue-gas drying, helps ignition and increases the heating value per pound. The pulverized coal maintains the desired combustion conditions.

While a boiler thus operated has somewhat less steaming capacity and slightly lower efficiency, these reductions are more than offset by the heat liberated from the garbage. Moreover, the arrangement permits flexibility in the burning of pulverized coal and waste to suit prevailing conditions. The important fact for Detroit, however, is the large saving in expense of garbage disposal, to which is added the kilowatt-hours credited to the garbage and some revenue from the sale of grease that is extracted.

It is likely that there are other cities and towns, having municipal power stations so situated as to make the Detroit plan applicable and profitable.

Cooperation Instead of Competition

MANY who a few months ago could see in the T.V.A. nothing but a threat to private utility properly and needless governmental competition, will find satisfaction in the announcement that the Authority has lately entered into contracts with the local power companies whereby cooperation is substituted for competition and threatened confiscation.

By the terms of the agreement the T.V.A. purchases the transmission and distribution systems, substations, etc., of the local companies in certain districts and agrees not to compete in the remaining districts for a period of years. Provision is made for interchange of power at mutually acceptable rates, dependent upon demand. Payment for the properties taken over is in most cases to be on the basis of sixty per cent of reproduction value, which seems fair, assuming that they have already been partly amortized.

The merchandizing plan to promote extensive use of electrical appliances as instigated by the T.V.A. will also benefit local private utilities in that Government credit will be behind such purchases.

It would appear then that, aside from the question of private or public ownership of power facilities upon which most people have decided opinions one way or the other, the experiment in the Tennessee Valley is likely to be carried out with a minimum of friction and full regard for the rights of the parties involved. This is in line with the broad pronouncements of Chairman Morgan shortly after his appointment to the Tennessee Valley Authority last spring.

As the President has often pointed out, the Tennessee Valley Development is a large-scale regional experiment in which power plays an important part, and the results are to serve as a yardstick for future guidance. It is too early to predict its influence on the general power situation, although a national power survey is contemplated. For the present, it is reassuring that T.V.A. power problems are being approached constructively.

Commercial Use of New Navy Compound

OUR attention has been called to an attempt by certain parties to commercialize the new Navy Boiler Compound as described in a paper by Commander Solberg and R. C. Adams at the Annual A.S.M.E. Meeting in December and published in the December issue of COMBUSTION.

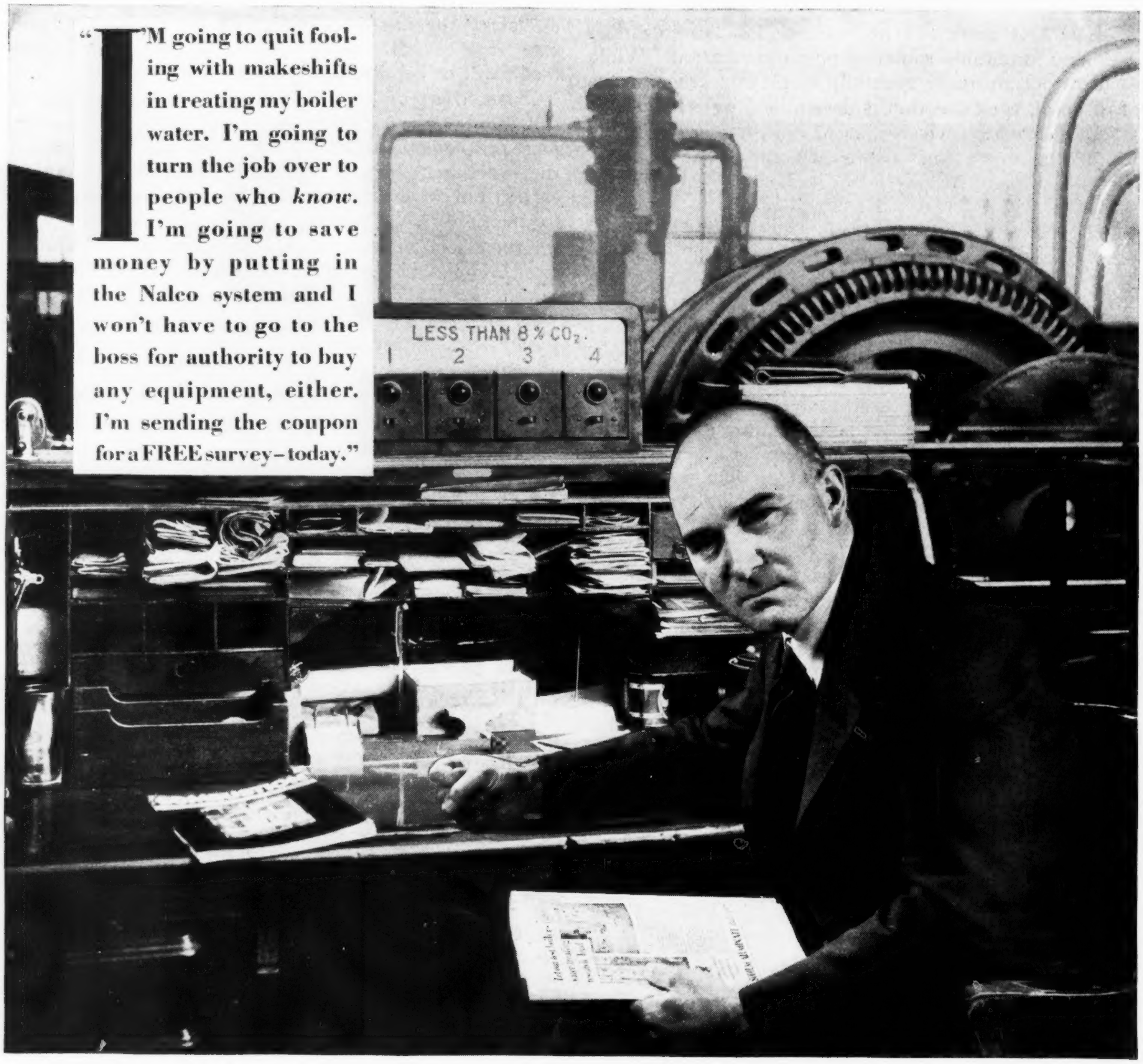
In this connection it is pertinent to refer to Commander Solberg's warning, at the time, that this compound had been evolved to meet the conditions peculiar to Naval boilers; that it was in no sense a panacea for boiler-water troubles; and that its use in land boilers or the merchant marine under certain conditions might be not only ineffective but actually hazardous. Similar views were expressed by many of those who discussed the paper.

Furthermore, the new compound was the result of tests carried out at the Naval Experiment Station at Annapolis. There has not yet been time to determine fully its effectiveness in the Service and such experience may well result in its modification. Even for Naval Service there are many feedwater authorities who doubt the value of the new compound. Some of these views were expressed in the January issue of COMBUSTION.

In view of the foregoing and the fact that intelligent feedwater treatment requires the application of expert knowledge to the individual case, it would be most unfortunate to have the new navy compound applied generally for conditions other than those for which it was intended.

The best time to make this resolution is *now!*

"I'M going to quit fooling with makeshifts in treating my boiler water. I'm going to turn the job over to people who *know*. I'm going to save money by putting in the Nalco system and I won't have to go to the boss for authority to buy any equipment, either. I'm sending the coupon for a FREE survey–today."



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Making Garbage Light City Streets

By L. J. SCHRENK, General Superintendent

Public Lighting Commission, Detroit

Experiments are being conducted on one boiler at the Mistersky Station, Detroit, whereby partly dehydrated garbage is burned in conjunction with pulverized coal. It is contemplated to modify two boiler furnaces for this purpose and on the basis of present tests the city will save approximately $100,000 per year in garbage disposal and at the same time generate 13,000,000 kw-hr as a by-product, to be available for street lighting and street railway use.

Fig. 1—View of furnace showing hearth and one water-cooled side wall; garbage enters at A

MAKING garbage to light the streets of a city or to drive street cars may sound like a fable, but that is exactly what the City of Detroit proposes to do, and in fact is now doing on a large experimental scale. Experiments with burning garbage under a steam boiler and using the steam for generation of electric power have been carried on for about five months. These experiments are conducted at the Mistersky Power Station of the Detroit Public Lighting Commission. One of the eight steam generating units at this plant which was designed for burning pulverized coal has been modified for burning partly dehydrated garbage and pulverized coal. On one of the runs made with this modified unit 10,166 lb of garbage and 6,667 lb of coal have been burned per hour, giving an average of 68,100 lb of steam per hour. Of this amount 10,100 lb of steam was generated from the burning of garbage which is sufficient to generate 900 kw. Further improvements in the preparation and the burning of the garbage should considerably improve the above performance. The object of burning garbage under steam boilers is not so much to reduce the cost of fuel to the power plant but to reduce the cost of the present disposal of the city wastes.

The waste material burned in these experiments is garbage only, consisting almost entirely of kitchen refuse and not containing any so-called combustible rubbish. As the garbage is collected and delivered to the plant it contains about 80 per cent of moisture. The ash content is 15 to 20 per cent and the heat value about 7500 Btu per pound on the dry basis.

Garbage is brought to the plant in the collecting trucks. It is then partly dehydrated in roller presses which dehydration reduces the moisture from 80 to about 65 per cent. There are two or three of these presses in series, each taking out a part of the moisture. The presses act in a manner similar to the old roller-type laundry wringer which wrings the water out of washed clothes. It seems quite possible to reduce the moisture in the garbage to about 55 per cent by proper adaptation of this type of a press to this particular material. Fuel thus prepared would have a heat value of about 3370 Btu per pound as fired. The lower the moisture content, the higher the efficiency with which this waste material can be burned under the steam boilers. High moisture content delays the ignition, reduces the furnace temperature thereby decreasing the rate of heat transfer and greatly increases the stack losses. Therefore, the preparation of the garbage to make it a better fuel for steam boilers is an important part of this method of disposal.

Removing moisture from the garbage by pressing it out, has the advantage over a drying process by heat in that it eliminates objectionable odors and makes possible the recovery of a large part of the grease contained in the garbage. A considerable part of the grease is squeezed out with the water and can be recovered with centrifugal machines and sold for the manufacture of soap.

The method of burning the prepared garbage in these experiments can be better understood by referring to Fig. 4 which is a section through the modified steam-generating unit at the Mistersky Station. The unit consists of a sectional-header boiler, an economizer and an air heater. The furnace was originally designed for burning pulverized coal and is 75 per cent water-cooled with bare tubes. The bottom of the furnace is cooled by a water screen which consists of a row of inclined tubes spaced on 10-in. centers and connected in the boiler-

water circulation. Over this water screen is placed a hearth or a grate for the burning of the garbage. This consists of rows of cast-iron tiles, 12 in. wide, with the lower edge over-lapping the upper edge of the next lower row of tiles about $^1/_2$ in. These lower edges of the tiles are provided with spacing pads about $^3/_8$-in. thick so that a $^3/_8$-in. air space is obtained between each row of tiles. This space between the rows of tiles is used for supplying air under pressure to the bed of burning garbage. Under the hearth or grate are four air compartments for supplying air under four different pressures varying from 1 to 6 in. of water, which pressure can be controlled by damper adjustment. The air so used is preheated in the air heater by flue gas to a temperature of 300 to 325 F.

Garbage is pushed into the furnace at the upper end of the hearth or grate by three rams or pushers. The rams are 32 in. wide and 6 in. high and are so spaced as to provide a bed of garbage covering the entire width of the hearth. The rams are operated by compressed air, but they can be also operated by low-pressure saturated steam. The length of stroke of these rams can be varied to any desirable length up to a maximum of 2 ft. Movement of the rams, combined with the downward slope of the hearth and the method of supplying air through the hearth, causes the bed of burning garbage to move over the entire length of the hearth. The movement of the rams and supply of the air is so timed that when the garbage reaches the lower end of the hearth practically all combustible has been burned out.

Pulverized coal, mixed with primary air, is supplied

Fig. 3—Results obtained from experimental dehydrater
354 lb green garbage gave 124 lb dehydrated material, 5.3 lb grease and 23 lb of mud extracted from liquid after taking out grease.

to the furnace through the ten burners located in the arch of the furnace. On the average about 2 lb of primary air is used per pound of coal. The coal ignites close to the burner and the burning mixture travels vertically downward along the front wall. Secondary air in the quantities required for complete combustion is supplied through air ports in the front wall as the burning mixture moves downward. When the mixture reaches an elevation about 2 ft above the lower end of the hearth it makes a U-shaped turn and flows upward along the opposite wall through which the garbage is supplied to the furnace. Thus, the lower nearly horizontal part of the U-turn passes closely over the bed of garbage and the high temperature of the coal flame supplies heat for drying and ignition of the garbage. The stream of burning coal moves in the opposite direction to the movement of the bed of garbage over the hearth.

The air supplied through the hearth and the bed of burning garbage is somewhat in excess to that needed for complete combustion of the garbage. This excess air is used for completing the combustion of the coal as the burning coal passes over the bed of the garbage. The secondary air supply through the front wall can be adjusted to the air supplied through the hearth.

Temperature in the furnace, within 2 ft above the bed of garbage, exceeds 2000 F and therefore insures complete combustion of any volatile products of the garbage which, if not consumed, would produce objectionable odor in the stack gases.

The experiments indicate that no serious difficulty from fusion of ash is likely to be encountered. The ash drops off the lower end of the hearth and is mostly in finely divided form. Some clinkers are formed but these are not too large to be hooked down by a hand tool inserted through doors in the furnace wall at the lower end of the hearth.

This modified furnace is suited to burn garbage and pulverized coal, or pulverized coal alone for periods of many hours so that the steam-generating unit can always be available for making steam for the generation of electrical energy. When the feeding of garbage to the furnace is stopped the air supply through the hearth is shut off. The combustion of the garbage on the hearth practically ceases and the garbage remains there indefinitely, thus protecting the hearth from the intense heat of the coal flame. The length of time during which coal can be burned alone is limited by the accumulation of coal ash over the bed of garbage.

From the dehydrating presses, which are located in a small building outside of the boiler room, the garbage

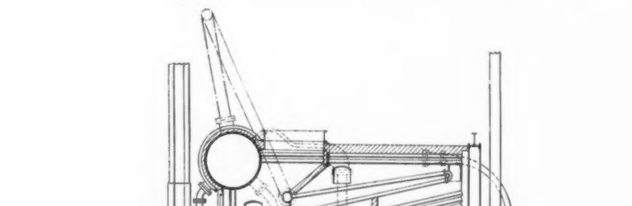


Fig. 2—Section through modified furnace

will be carried by belt conveyors to the hoppers above the rams which feed the garbage into the furnace. The conveyors handle the garbage without any difficulties.

In a recent test 164,650 lb of garbage as collected was delivered to the preparation house containing the dehydraters. From this garbage 13,150 lb of tin cans and uncombustible rubbish was removed as it passed to the dehydrater, leaving a net weight of 151,500 lb. Moisture analysis showed this material to contain 119,500 lb of water or 79 per cent, leaving 21 per cent or 32,000 lb of combustible matter with approximately 15 per cent ash. After passing the garbage through the dehydrater 60,000 lb of water was removed, giving a dehydrater efficiency of 50.4 per cent. The prepared garbage, as fed to the furnace, then contained 65 per cent moisture.

The following results were obtained over a nine-hour test:

Total prepared garbage consumed	91,500 lb
Garbage consumed per hour	10,166 lb
Pulverized coal consumed per hour	6,667 lb
Heat value of garbage as fired	2,800 Btu
Average rating of boiler, steam per hour	68,100 lb
Average steam produced from the garbage, per hour	10,100 lb
Average CO_2	11.9 %

From other tests it appears quite possible to prepare garbage with 55 per cent moisture and consume it in the furnace at the rate of six tons with 2 to 2 $^1/_2$ tons of coal per hour. If the unit is operated 24 hr per day the total garbage consumed would be 144 tons per day. However, on the basis of 55 per cent moisture for the dehydrated garbage and 80 per cent moisture for the garbage as collected, the dehydration process reduces 2$^1/_4$ tons of garbage as collected to 1 ton of prepared garbage. Therefore, if the furnace will consume dehydrated garbage at the rate of 144 tons per day it will dispose of 324 tons per day of the raw garbage. The operation of such a unit 24 hr per day 5 days per week would make it possible to dispose of 1620 tons of garbage as collected.

So far the experiments have been confined to burning garbage. No rubbish or mixture of garbage and rubbish has been tried. The combustible part of the ordinary rubbish consists of paper, wood, cloth, leather, bedding and similar house waste materials. The moisture content is usually much lower than that of the garbage, averaging about 35 per cent. Because of this lower moisture content the rubbish could be burned much more readily than garbage and would make a better steaming fuel. The rubbish will be prepared by passing it through a lacerating machine to reduce it to a uniform size so it can be handled by the conveying and furnace-feeding equipment.

At the present time it is contemplated to rebuild two furnaces. It is expected from test results to dispose of approximately 50,000 tons of raw garbage and 27,000 tons of combustible rubbish annually at this power station.

Since it costs the City \$2.25 a ton through present methods to dispose of the garbage after being collected, it is estimated that the proposed method will easily result in a saving of \$100,000 annually to the taxpayer in this one item alone.

In addition to this direct saving, test results have shown that approximately 13,000,000 kwhr of electrical energy can be generated annually and will be available for street and building lighting and for the operation of the City's street railway system.

Pittsburgh Award to Doctor Hall


Dr. R. E. Hall

The Pittsburgh Section of the American Chemical Society has selected Dr. Ralph E. Hall, Director, Hall Laboratories, Inc., Pittsburgh, as the recipient of the 1933 (the first) "Pittsburgh Award," which is in the form of a gold plaque symbolizing the relation of chemistry to industry.

This honor, which will be conferred at the sectional meeting on February 15, has come to Doctor Hall "in recognition of his distinguished service to chemistry and humanity, particularly his contributions to the fundamental knowledge of boiler-water reactions and their applications to the practical solution of boiler-water problems, his discoveries and technical accomplishments in the beneficiation and conditioning of water for industrial and domestic use and his developments in the production of chemicals for these purposes."

Doctor Hall and his work are well known to engineers in the steam field, but a brief review of his earlier activities are pertinent at this time. Following graduation from Ohio Wesleyan University in 1907, he taught chemistry and physics in Ohio high schools for several years; was Fellow and Associate at the University of Chicago from 1914 to 1916 and the following year taught at Iowa State College. He received his masters degree from Ohio State University in 1911 and the Ph.D. degree from the University of Chicago in 1916.

In 1917 he became physical chemist at the Carnegie Institution of Washington, remaining there until 1920 when he became director of physico-chemical research at the Firestone Tire & Rubber Company. The following year he joined the Koppers Company and in 1922 became physical chemist of the U. S. Bureau of Mines where his notable researches into boiler-water problems began. He resigned in 1926 to become Director of Hall Laboratories, Inc.

Doctor Hall is a member of the American Chemical Society, the American Society of Mechanical Engineers and the American Society of Testing Materials.

The Federal Power Commission in its thirteenth annual report, just made to Congress, urges that it be granted supervision over holding companies that control operating companies licensed under the Federal Water Power Act. Most of the water-power projects that have been so licensed are controlled indirectly by holding companies and the Commission has found it difficult to determine the costs of many of these projects. Many items claimed by the licensee as part of the construction costs arise from intercorporate contracts and at present the Commission is unable to scrutinize the books of the holding companies. Extension of the Commission's authority as requested would remove this obstacle.

Air Leakage in Steam Generating Units

By W. S. PATTERSON
Combustion Engineering Company, Inc.

PART I PRELIMINARY DISCUSSION

The occurrence and approximate magnitude of air infiltration has long been known, but, judging from the dearth of printed literature on the subject, it appears not to have been given the attention warranted by its importance. Extensive use of air preheaters in the past ten years has led to the discovery that the preheater heat balance may be used as an indicator from which to judge the magnitude of air leakage or infiltration in certain parts of the system. The present article is a preliminary treatment of the subject to be followed by a discussion in numerical terms of the magnitude, variation, measurement and effects of air infiltration in various parts of steam-generating units.

Air and the Combustion of Fuel

IN THE combustion of fuels the generation of heat results from the exothermic chemical reactions between the element oxygen, the sole supporter of combustion, and the combustible elements in the fuel, namely carbon, hydrogen and sulphur. The heat or calorific value of any fuel as listed in text or reference books is the quantity of heat, expressed in British thermal units or calories, resulting from the complete combustion of a unit weight of the fuel with oxygen, in a fuel calorimeter wherein the combustion products are cooled down to the original temperature of the fuel and oxygen. If the required oxygen were obtained by using air in the calorimeter the same heat value for the fuel would be obtained provided the combustion products were cooled down to the temperature of the entering components of the reaction. However, if the combustion products in both cases are allowed to escape at a temperature higher than that of the initial components, more heat will be lost in the latter case, where air is used for combustion. This is due to the fact that air contains about 77 per cent nitrogen by weight which does not take part in the combustion reaction but which carries away sensible heat if allowed to escape at a temperature higher than that of the initial air temperature.

A fuel-burning, steam-generating unit may be compared to the fuel calorimeter. In the latter all the fuel must be burned and all the heat in the combustion products must be recovered and measured in order to determine the true heat value of the fuel. In the former the more heat from the fuel fired that is utilized the more efficient is the unit, but it is impossible to build a commercial steam-generating unit of 100 per cent efficiency. The more important reasons for this are: first, the lowest temperature cooling medium usually available for recovery of heat from the combustion products is the air, which is at the temperature to which it is desired to cool the combustion products; second, in the commercial apparatus, atmospheric air must be used for combustion; third, an excess of air over that required to give the theoretically necessary oxygen must be used; fourth, all the combustible in the fuel fed to the furnace generally cannot be burned; and fifth, there may be considerable air infiltration between the point at which combustion starts and the point at which the gases are expelled from the last piece of heat-recovery apparatus in the unit. It is the fifth and last of these which is to be the subject of this article, but the others may well be discussed briefly in passing.

As pointed out in connection with the fuel calorimeter it makes no difference whether the fuel be burned with the quantity of oxygen or air theoretically required or with an excess, so long as the resulting combustion products are reduced in temperature to that of the entering components of the reaction, at which temperature their heat content above this datum is zero. The difference in heat-recovery efficiency between fuel burned with theoretical oxygen or theoretical air, or an excess of air depends therefore on the temperature at which the combustion products are expelled.

The important heat-recovery components of a modern steam-generating unit are the furnace, the boiler, the superheater, the water economizer and the air preheater. The first two, three, four or all five of these may constitute the unit. The minimum temperature to which the gases leaving a conventional type boiler may be reduced, will obviously approximate closely the temperature of the saturated steam within. In the water economizer the minimum gas temperature leaving a true counterflow design would approximate that of the entering water; and in a counterflow design air preheater, that of the entering air. But in each of these cases the stated minimum temperature can be obtained only by the use of an infinite amount of surface which is not commercially practical. Therefore, the combustion products leaving a steam-generating unit are never reduced in temperature or heat content to the desired low level, and the fact that fuels must be burned with air, and even supplied with an excess of air, becomes an important factor in the consideration of heat-recovery efficiency.

Fuel cannot be burned efficiently without an excess of air over that needed to furnish the oxygen theoretically

required to complete the chemical reactions with the carbon, hydrogen and sulphur. This is particularly true of solid fuels such as coal and wood because of their high fixed carbon content which makes it impossible for all the carbon molecules to be brought intimately in contact with the oxygen molecules, if the quantity of the latter present has been limited to only that theoretically required. And when it is considered that the oxygen in the air is intimately mixed with about four times its volume of nitrogen, whereby it is to a certain extent separated from the fuel, it is not surprising that, even in the combustion of gaseous and highly atomized liquid fuels, considerable excess air must be furnished. Generally speaking, a deficiency of air results in volatile combustible losses when burning solid fuels on grates, and gaseous and liquid fuels. It results chiefly in solid combustible loss when burning solid fuels in suspension. Too much excess air will in all cases result in increased loss of sensible heat in the waste flue gases for two reasons: first, the weight of combustion products is increased for a given weight of fuel burned, which results in higher temperature gases leaving the steam-generating unit; and second, the weight and temperature of the products both being higher, the heat loss is higher.

This brings us again to the subject of this article, namely, air leakage and air infiltration. Excess air, as explained, is intentionally delivered to a furnace to aid and to complete as far as possible the combustion of the fuel; but air is also unavoidably or carelessly admitted to fuel burning furnaces as the result of leakage or infiltration. This latter is really nothing more than excess air, but since it enters at various places along the path of the products of combustion all the way up to and including the chimney, and since it has different effects on the operating results of the unit, depending on where it enters the system, it is generally, and will hereinafter be, referred to exclusively as *air infiltration*. It may be defined as the leakage of air from the outside surroundings of a steam-generating unit at atmospheric pressure to the hot gas stream within, under pressure below atmospheric, such leakage being not readily controllable since it takes place through small cracks, around doors, expansion joints, duct joints or through porous brickwork.

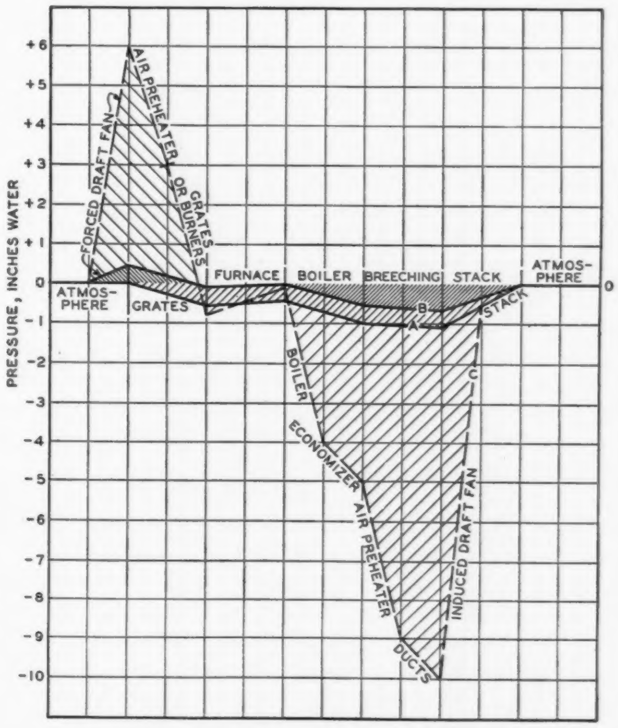
Air Infiltration in Furnaces

Since air infiltration occurs because of the pressure differential existing between the atmosphere surrounding the furnace and that within, consideration must be given to the various types of furnaces and methods of burning fuels insofar as they affect this pressure differential.

Previous to the introduction of the centrifugal fan, or fan blower, as a substitute for or auxiliary to the chimney, in about 1825, all fuel burned in boiler furnaces was fired on stationary grates and the air supplied by means of natural (chimney) draft. In this system the chimney has to produce enough draft to overcome the resistance which the fuel bed and the boiler tubes offer, respectively, to the flow of air and the products of combustion. The sizing of the fuel, the rate of combustion per square foot of grate, and to a certain extent the nature of the grate, determine the fuel-bed resistance. The design of the boiler determines its resistance or draft loss but, generally and comparatively speaking, the boiler which gives the highest efficiency will have the highest draft loss, other things being equal. Curve *A* of Fig. 1 shows the variation in pressure for such a natural-draft installation. It is obvious that the entire setting of such a unit is subject to air infiltration and that in a hand-fired installation immense quantities of air would rush through the fire-doors when opened. The importance of reducing such controllable infiltration was thoroughly appreciated even in the days before the value of mechanical draft became well established. A publication dated 1876,[1] describing tests to determine the influence of the frequency of hand firing, refers to an arrangement whereby the boiler damper was closed or nearly so when the fire-door was opened. A discussion of the infiltration of air through brick settings was given by J. C. Hoadley in a book published in 1886,[2] and the use of flue-gas analysis to detect infiltration between the back and uptake flue of a battery of horizontal return-tubular boilers is referred to in an old catalog of a well-known fan manufacturer.[3] The battery consisted of three boilers. With all three operating, the percentage of air which leaked in between these two points was 15.4; but with only the middle boiler in operation, and with dampers on the other two boilers closed and packed, the leakage was 22.1 to 27.6 per cent due to the increase in ratio between the exposed surface of the setting and the volume of gas passing through the uptake flue.

Total air supply by natural draft is still used in connection with many hand-fired and some stoker-fired coal burning furnaces. It is also used with oil- and gas-fired furnaces. In general, it is only used where the desired fuel-burning rate requires not more than 0.50 in. (water gage) draft in the furnace to induce the proper amount of air for combustion.

(1) Bulletin de la Société Industrielle de Mulhouse, Vol. XVVI
(2) Warm Blast Steam Boiler Furnace, J. C. Hoadley, New York, 1886.
(3) Mechanical Draft, B. F. Sturtevant Co. Catalogue No. 98 dated 1898.



Curve A for small unit employing natural-draft air supply.
Curve B for same unit employing forced-draft air supply.
Curve C for large unit employing mechanical forced- and induced-draft equipment in conjunction with modern auxiliary heat recovery apparatus.

Fig. 1—Variation in pressure of air and products of combustion in steam-generating units of various types

Historically, the first step in the application of mechanical draft to steam-generating units was the use of a fan to supply air under pressure below the grates of hand-fired furnaces. The natural draft produced by a chimney was still used to remove the combustion products from the furnace. This modification and improvement had the effect of reducing the draft or negative pressure required at any point in the system beyond the grates.

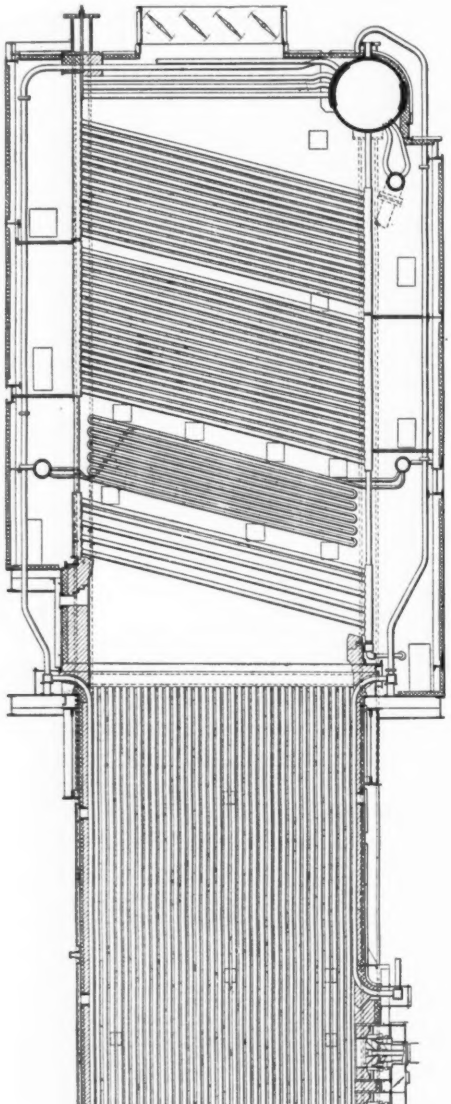


Fig. 2—Modern pulverized fuel fired steam-generating unit designed for 325,000 lb steam per hour and 311 F superheat, employing forced-draft air supply but relying on natural stack draft for removal of products of combustion

It therefore reduced the height of chimney required, and by reducing the air infiltration it also reduced the required stack diameter and at the same time improved efficiency. Curve *B* of Fig. 1 shows how Curve *A* would be changed by the substitution of forced-draft air supply. It is obvious that, other things being equal, air infiltration under such conditions would be much reduced.

Many large and modern steam-generating units employ forced-draft air supply in connection with natural draft removal of the combustion products. Fuel burning rates have been greatly increased by the use of forced-draft mechanical stokers of various types, and forced-draft, pulverized fuel, oil and gas burners. Combustion air is supplied under positive pressure in some cases in excess of 5 in., water gage. Fig. 2 illustrates a pulverized-fuel-fired unit falling under the above classification.

Another step in the application of mechanical draft to steam-generating units was the use of a fan to assist or practically replace the chimney as a means for providing the pressure necessary to remove the products of combustion. The modern use of high fuel combustion rates, high-pressure steam, water economizers and air preheaters has greatly increased the pressure required to remove these products, to the point where it would be impracticable to build a chimney of the size required. The modern high efficiency unit therefore has both forced- and induced-draft fans. Curve *C* of Fig. 1 shows the variation in pressure for such an installation, as illustrated by Fig. 3.

So far as air infiltration into the furnace is concerned it makes little difference whether the gases are removed by natural or mechanical induced draft. In either case it is customary in modern furnaces to operate with a slight negative pressure at the point of highest elevation in the furnace. This precaution is necessary in order to protect the furnace walls at this point and to prevent the escape of hot gases from the setting. The differential pressure across the furnace walls near the top is therefore very small and air infiltration in this region is negligible. However, in a furnace of great height such as is shown in Fig. 3 the negative pressure in the lower part of the furnace will be appreciable. The furnace shown has a maximum height from ash hopper to apex of over 80 ft. If the average temperature of the gases in the furnace were 2000 F the negative pressure in the lower part of the furnace might be 0.90 in., water gage, even though the pressure were practically atmospheric at the top. This is due to the stack effect of the hot gases, which, although somewhat variable depending on the method of firing, is primarily dependent on the average furnace temperature, outside air temperature and height of furnace. It is obvious therefore that the air infiltration in the lower part of a large furnace may be very great. This depends, however, very largely on the furnace design, some important features of which will now be discussed.

Proper furnace design, insofar as it affects air infiltration, depends primarily on the kind of fuel, method of firing and type of boiler. These factors affect the required furnace shape, size, height and to some extent the number of possible cracks, in the lower part of the furnace, through which the leakage air may pass. It is obvious that, since all solid fuels leave ash in the furnace, some means for removal must be provided either in the form of hoppers, a sluicing system, screw conveyors or similar apparatus. This ash removal equip-

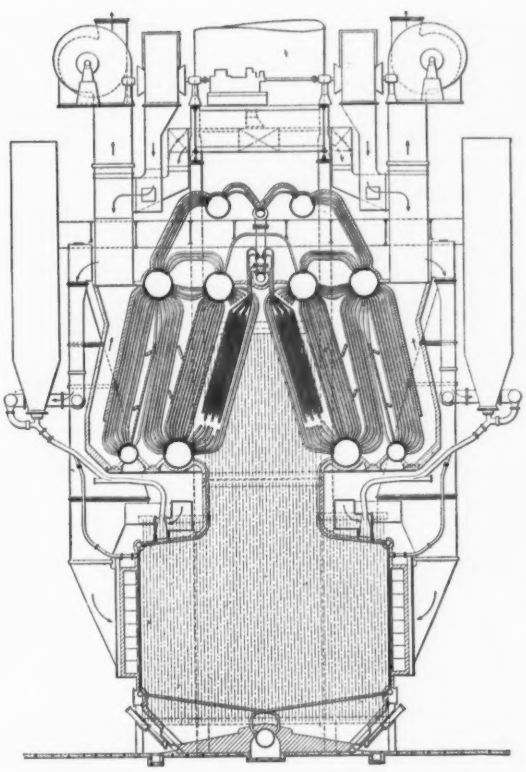


Fig. 3—The largest capacity steam-generating unit in the world, pulverized fuel fired, consisting of three pass bent-tube boiler, integral economizer, air preheater, and employing both forced- and induced-draft fans

ment, being located in the zone of maximum negative pressure, and being in many cases inherently susceptible to leakage, accounts for much of the air infiltration. The use of a slagging bottom furnace similar to the type shown in Fig. 4 provides a method of ash removal which eliminates most of this infiltration and at the same time decreases the over-all furnace height required. Furnaces for all fuels, regardless of the method of firing, require access and observation doors, most of which are located toward the lower part of the furnace. Generally speaking, furnaces for burning solid fuels require more doors in this zone than oil- or gas-burning furnaces. These, in addition to the furnace-bottom hoppers which are not used on oil and gas fired installations, may result in more air infiltration if not properly sealed.

The kind of fuel and method of firing affect also the furnace size and shape. Solid fuels when burned on stokers, oil and natural gas require less furnace volume than solid fuels burned in suspension. The furnace volume in turn affects the wall area surrounding it which, in turn, may materially influence the rate of air infiltration. Fuels such as oil, gas and pulverized coal, when fired horizontally require a certain depth of furnace from front to rear; fuels when fired vertically require a certain height of furnace. The height of furnace affects air infiltration because the maximum pressure differential across the furnace wall, which causes the leakage, is directly proportional to the height.

The type of boiler affects air infiltration in the furnace because it governs the furnace height. For instance, comparing the bent-tube boiler of Fig. 5 with the straight-tube boiler of Fig. 6, the point at which a balanced draft or slight negative pressure must be maintained is the point of highest elevation in the furnace. It is obvious therefore that this point of minimum draft, or maximum pressure in the furnace is farther from the furnace bottom in a bent-tube boiler installation, other things being equal, such as method of firing, capacity, etc. Therefore, the negative pressure near the furnace bottom of the bent-tube boiler unit will be greater.

The human element also enters into the problem when it is considered that some firemen are very careless about keeping furnace observation doors closed. The author has noticed firemen on pulverized fuel installations who operated with several small observation doors in the lower part of the furnace continually open. This was apparently done because it required less effort to observe the condition of the fire. Some firemen are also careless about operating with too much draft in the furnace. This happens most frequently after a reduction in load because the operator first reduces the air supply to the furnace by regulation of the forced-draft fan and then neglects to reduce the furnace draft by closing the boiler damper or regulating the induced-draft fan. The result is that, where a steam flow-air flow meter is used for boiler control, it is possible to get the desired setting of the steam and air pens for a considerable reduction in steam load without regulation of the furnace draft. Under these conditions, however, much air enters the furnace by infiltration.

Air Infiltration in Boiler, Economizer, Air Heater and Ducts

In the apparatus which follows the furnace the pressure differential tending to cause air infiltration is generally much greater than in the furnace, but the enclosing surface is much less. Installations having pressures of −5, −9 and −13 in., water gage, respectively, at boiler, economizer and air-heater outlet, are not uncommon. In such instances, however, precautions must be taken to prevent air leakage, and an understanding of where infiltration is most likely to be found is important to designer and operator alike.

In the boiler setting the places to look for leaks depend on the boiler type. Nearly all makes of boilers are supported from the top and expand downward. In bent-tube boilers the drums, two, three or four in number, generally extend into or through the setting and may be sealed only by means of a compressible packing which after being compressed several times may stay compressed and cause a leak. At least a portion of the openings so formed will be found in the last boiler pass where the negative pressure is greatest; hence a good place to look for infiltration. In straight-tube boilers relative expansion between headers and setting is taken care of by packing, and in the sectional-header type the spaces between headers are also packed. Large tube removal doors extending completely across the setting confine the leakage to cracks around their edges. Brick boiler settings, although in apparently good condition may be very leaky. Their condition may be checked by "candling," but the total air infiltration resulting from leakage around doors, drums, expansion joints, superheater tube holes, soot blowers and through porous brickwork may be quite accurately calculated from gas analyses taken entering and leaving the boiler surface. An unusually large number of access doors were provided in the boiler setting illustrated in Fig. 4.

Economizer surface is generally more compactly ar-

ranged than boiler surface, and steel encased as illustrated by Fig. 5. The absence of access doors to the interior tends to minimize leakage although the negative pressure within may be very high. The tube ends are connected by means of small headers, junction boxes or simple return bends and several methods of sealing against leakage are used which may or may not be effective. However, it is possible to construct tight doors for the two ends of the economizer so that practically no infiltration can be measured or detected.

Air-heater surface is also compactly arranged and steel encased to minimize leakage. In the plate-type heater, air may leak from the room into the gas passages through the casing or from the air passages into the gas passages. When completely welded elements and expansion joints are used leakage of the latter type is eliminated; and, by using care in constructing the casing, leakage from the room inward will be in most installations so small as to be unmeasurable. In the tubular-type heater where the gases pass through the tubes, there is no infiltration in the heater proper. There may be, however, some air leakage between the air under positive pressure surrounding the tubes and the gas stream which is under negative pressure. This occurs because, in order to allow for relative expansion between tubes and casing, the tube ends are generally expanded loosely into one of the tube sheets. In the rotating type regenerative heater infiltration is greater than in the plate or tubular recuperative types because it is more difficult to provide a tight seal between the air passage and the gas passage, and because the rotor is continuously carrying air, contained therein, into the gas passage to be discharged with the gases.

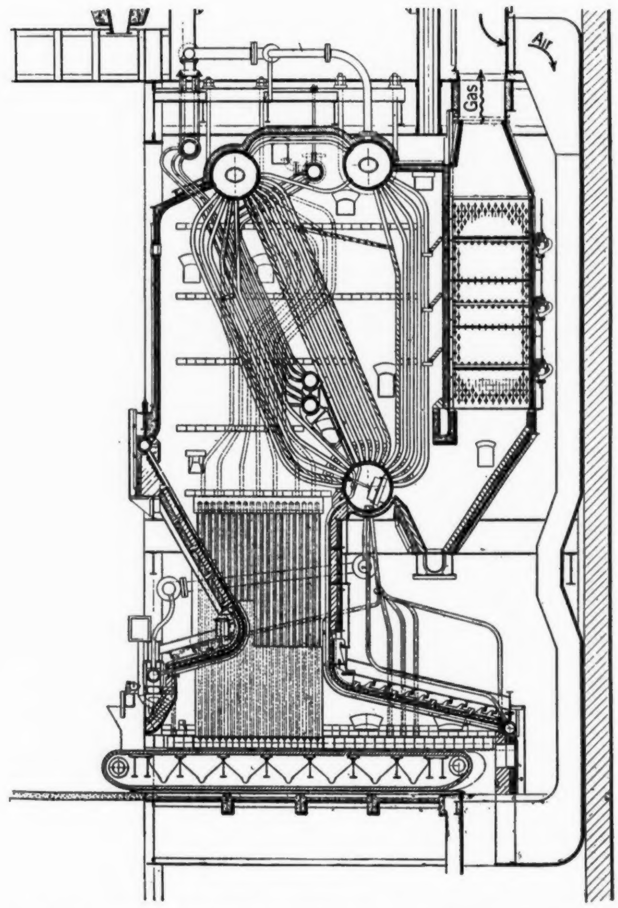


Fig. 5—Chain-grate stoker with completely water-cooled, combination arch-type furnace used in conjunction with three-drum bent-tube boiler, fin-tube economizer and air heater

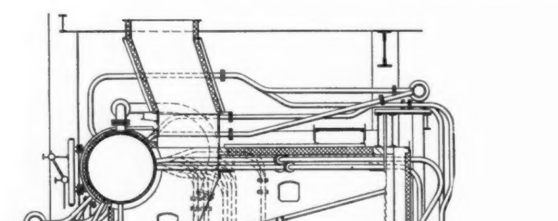


Fig. 4—"Slag-tap" or "wet bottom" furnace for pulverized fuel firing which eliminates the necessity for ash hoppers, ash gates, and the ineffective furnace volume otherwise provided below a water screen, as in Figs. 2 and 3

Because each piece of apparatus such as boiler, economizer, air heater and fan, is generally independently supported, expansion joints are necessary in the connecting duct work. These may be very leaky affairs if not properly designed for the required service. Much of the air infiltration sometimes blamed on an economizer or air heater may be due to leaky expansion joints or connecting ducts. If, for instance, a leaky expansion joint is located very close to the gas inlet flange of an economizer it will not be detected by analysis of the gas entering the economizer but will show up falsely as economizer infiltration in analysis of the gas leaving the apparatus.

The Importance of Air Infiltration

The importance of air infiltration depends on its magnitude, location, the kind of fuel, method of firing and rate of combustion in the furnace. It is obvious that leakage of air into a steam-generating unit beyond the point where active combustion has ceased, can only be wasteful of energy. Such infiltration, while it does not instantly change the heat content of the gases measured above the datum of room temperature, decreases the temperature difference between gases and heat-recovery

surfaces, increases the gas weight and therefore the friction loss, increases the required size of stack or induced-draft fan and actually decreases the thermal efficiency of the steam-generating unit.

Air infiltration in the furnace may or may not affect the overall efficiency of the unit. One might think that since most air infiltration takes place, as explained, in the lower part of the furnace, such air would enter into chemical reaction with the fuel, with the net result that the efficiency of the unit would not be impaired. This would be the case if the air entering the furnace through leakage were admitted in the proper place in the proper proportions and if no air preheater were used for waste heat recovery. But any air which leaks into a furnace and is used effectively in the combustion of the fuel robs the air heater of an equivalent weight of air, thereby decreasing its heat-recovery efficiency. The net effect is a decrease in the overall unit efficiency by an amount equal to the decrease in air preheater efficiency, both being expressed in terms of the gross heat input to the unit.

Consider also the case where the furnace air infiltration does not take part in the combustion process. This condition will generally be found to exist in all furnaces at low rates of combustion when flame does not completely fill the furnace. In this instance more air will be handled through the air preheater because more total air, including the infiltration, must be handled by the furnace. In other words, the excess air supply, calculated from analysis of gas leaving the furnace will be higher, which means a greater gas weight flowing through the heater. Again we find the air preheater efficiency decreased because, as in the previous instance, the ratio of gas weight to air weight flowing through the air heater is greater than if the furnace were tight and free of infiltration.

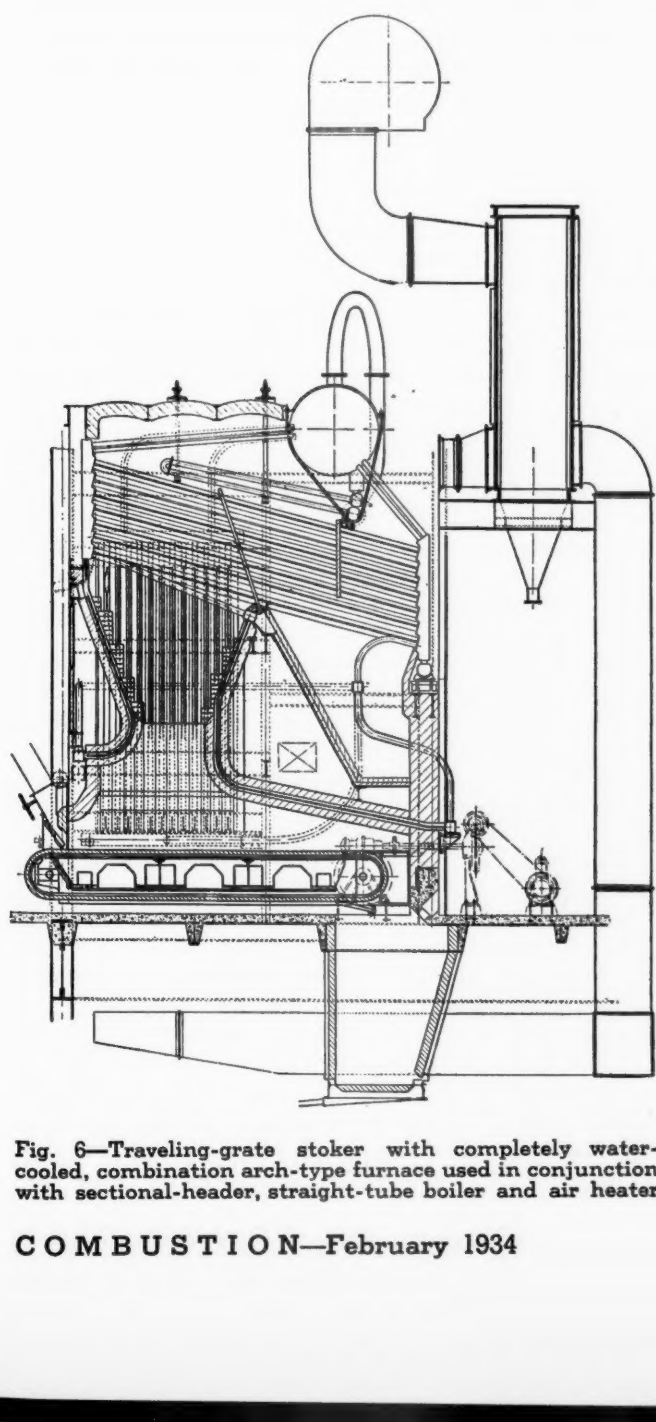


Fig. 6—Traveling-grate stoker with completely water-cooled, combination arch-type furnace used in conjunction with sectional-header, straight-tube boiler and air heater

However, it will be noted from curve *C* of Fig. 1 that between the forced-draft fan outlet and the furnace there is considerable opportunity for air to leak out of the system into the surroundings. Therefore, all the air which passes through the air heater may not be delivered directly to the furnace. This is particularly true in the case of stokers where huge windboxes are provided beneath the grates. Unless these are made very tight the outward leakage from the windbox may be as great as the inward infiltration of the furnace. Air-heater efficiency under these conditions would be high but, obviously, much of the heat recovered would be lost again through air leakage.

The extensive use of air preheaters during the past ten years has brought to the fore the importance of air leakage and infiltration. The seeming unbalance of heat input to heat output sometimes found in the air preheater may be used as a means for calculating the percentage of air infiltration into the furnace and boiler setting. Subsequent articles will discuss in numerical terms the magnitude, variation, measurement and effects of air infiltration in various parts of steam-generating units.

Donavon B. Church has been transferred from the San Francisco branch office to the factory engineering department by the Mason-Neilan Regulator Company, Boston, Mass., manufacturers of automatic regulating and control equipment.

The Hays Corporation, Michigan City, Ind., announce the following new representatives in several territories: State of Kansas and Western Missouri, T. C. Messplay, Kansas City, Mo.; State of Washington, Fairman B. Lee, Seattle; Eastern Tennessee, Leinhart Engineering Co., Knoxville; and Western Michigan, Engineering Sales Co., Holland, Mich.

The 1933 Index to A.S.T.M. Standards and Tentative Standards is now ready and appears in the December issue of the American Society of Testing Materials Bulletin. With the number of Society standards and tentative standards now totalling 689, the index is not only a decided convenience in finding a specification but is also helpful to purchasing agents, materials engineers and other concerned with specifications and test methods in determining whether the A.S.T.M. has issued any standards on a specific subject. Copies are furnished without charge upon request to the Society Headquarters, 260 South Broad Street, Philadelphia.

Short-Cuts and Extrapolations in Testing Metals at High Temperatures. Shall it be Attacked?

The Joint A.S.T.M. and A.S.M.E. Committee on Effect of Temperature on the Properties of Metals, after reviewing the problem of long-time testing and the limitations of short-time tests for design purposes, proposes a program of simultaneous correlation with the same materials. To start with, one ferritic and one austenitic steel would be subject to three-year creep determinations at three loads and predetermined temperatures. At the same time, these materials would be subjected to accelerated tests, and suggested methods of extrapolation compared with the actual results of the three-year test. The Committee solicits comments on the proposal.

THE Joint Research Committee on Effect of Temperature on the Properties of Metals, the agency set up by the A.S.T.M. and A.S.M.E. to deal with the field denoted by its name, discussed at its last meeting a problem that is looming large in the eyes of engineers who design, who test and who use alloys at high temperatures.

The logical base line for high temperature design, comparable to the tension test for ordinary temperature design, and like it subject to varying factors of safety dependent on the particular type of service, is the stress for a given amount of deformation, determined by tests, each at one constant temperature and one constant load. This requires a family of curves obtained by long-time "creep" tests.

As is usual in the development of a new type of testing, early results were shrouded in uncertainty because it was not clear whether the discrepancies and discordances in the results of different observers were due to inaccuracies in the method of test, such as insufficient realization of the necessity for precise temperature control, too short periods of test, etc., or to real differences in supposedly similar lots of material. The testing difficulties appear well on the way toward being smoothed out by the promulgation last June of a Tentative Creep Test Code which summarizes in a few essentials of procedure the experience of the Committee members and of those of its many sub-committees. It appears that results of different observers, all adhering to the code, will hereafter show vastly better agreement than some of the older data did, and that the way is thus paved for true appraisal of the actual differences among materials and, in the case of a single material, of the determination of its load-carrying properties. Determination of the spread in load-carrying ability between different lots of material of the same class, so that the designer can intelligently fix "safe loads"—for which the user is clamoring—must await the accumulation of data on lots of known history.

In most cases design cannot wait for this accumulation, so the designer has to make the best guess he can. He knows that the short-time high temperature tensile test by itself gives high values, which, if they have any real value at all in design for structures to be subjected to long loading, must certainly be modified by large factors of safety which must increase, as the temperature is increased, and increase to such large magnitudes that the shakiness of the assumptions made becomes self-evident. The designer feels more security in having creep values, from say 1000-hr tests, as a basis for extrapolation to the years of actual service he desires, but at best he must still extrapolate and must, while lacking actual data, make assumptions as to the conformity of the behavior of the material he uses with available data for behavior of other material of that type that has been previously tested.

Pressure is therefore put on the testing engineer to provide quicker returns when a given lot of material is submitted for high-temperature appraisal. The suggestions for short-cuts have been many. They range from the super-refined determination of short-time proportional limit, through deformation measurements carried on for a day or so, "relaxation" tests starting at high loads automatically reduced, other tests starting at a high temperature with temperature automatically reduced, through cantilever tests, restrained bend tests, step-up and step-down tests on a single specimen, etc., down to the abandonment of all short cuts and the use of the recognized creep method with the aim of carrying it on only for just the period required to show clearly the future behavior of the material. Lack of knowledge as to when the test really becomes sufficient makes this aim difficult of fulfillment, especially since the question of metallurgical stability arises, so that another angle of the problem is how to "incite" metallurgical breakdown or stabilization, as the case may be, by shortened methods.

Proponents of suggestions for short-cuts normally advocate them primarily for "sighting shots" to reduce the necessary number of creep tests, or for appraisal of the uniformity of a given material from lot to lot rather than as a true foundation for design values, but either the proposer of the short-cut or someone who reads or hears of it, ultimately attempts to find some conversion formula by which the short test can be made to tell the long story.

Either some such conversion is possible, or none is. Enthusiasm may lead to adoption of an untrue conversion

and resulting disaster on the one hand or wasteful use of metal on the other. Conservatism may lead either to excessive cost of testing by sticking to the old ways or to parsimonious failure to make tests where tests are vitally needed, preferring to take chances than to spend money. Progressive engineers have an open-minded attitude toward accelerated methods but at the same time one that demands engineering proof of, instead of mere hope of, correlation.

The Joint Committee has, in its ten years of existence, assembled and disseminated much basic information on the relation between high-temperature fatigue and creep, the effect of grain size, etc., and on the broad problem of stability of alloys at high temperature, a metallurgical aspect that must always be considered, and has on its immediate program or those of special sub-committees constituted for the purpose of planning, financing and carrying them out, specific problems on specific alloys whose clarification will advance fundamental knowledge.

A similar Joint Committee recently formed in England for the study of high-temperature problems is reported by the British engineering press as in progress of financing, jointly by industry and the government, and on quite an extensive scale, a three-year research program. British editorial comment refers to support of the program as a patriotic duty for the maintenance of British progress against the advances resulting from high-temperature research in other countries. The broadest task of such Joint Committees is to develop acceptable methods for evaluation of high-temperature properties which industry may use to get the specific data required on specific alloys as new alloys are suggested for high-temperature service, or to appraise the uniformity from lot to lot of older alloys.

The correlation of long duration, research-type test methods and rapid shop or acceptance test methods was one of the original purposes for which the American Joint Committee was formed and which has had constant consideration in its councils. Until recently, the creep determination itself was hardly on a firm enough foundation to serve as a useful base line for the comparison. Today it seems, while still subject to improvement and still calling for experience and engineering judgment in its application, to be usable as such a base line.

The Committee is therefore suggesting that a correlation program should be undertaken wherein, as a minimum, one ferritic and one austenitic steel, each most carefully chosen for metallurgical uniformity and stability, would be subjected to creep determinations, at a temperature in each case chosen in view of the recognized uses for such materials at those temperatures, and at three loads, chosen to produce creep rates of the order considered allowable in industrial use. These creep tests would continue for three years and be made under all the refinements of the A.S.T.M.-A.S.M.E. Tentative Code.

Meanwhile, the same materials would be subjected to the various accelerated or short-cut methods that have been proposed, and various methods of extrapolation from one load to another that have been suggested, would be applied. From these methods the rate of creep for three years would be predicted according to the procedure used by the proponents of each method, and later compared with the actual results of the three-year test. Material would be held for use in other short-cut methods that may arise later, and for possible international comparisons of methods.

Instead of waiting for comparisons of each short method with regular creep to be made upon whatever materials the experimenter has available, with consequent difficulty of correlation, simultaneous correlation would thus be obtained on the same materials.

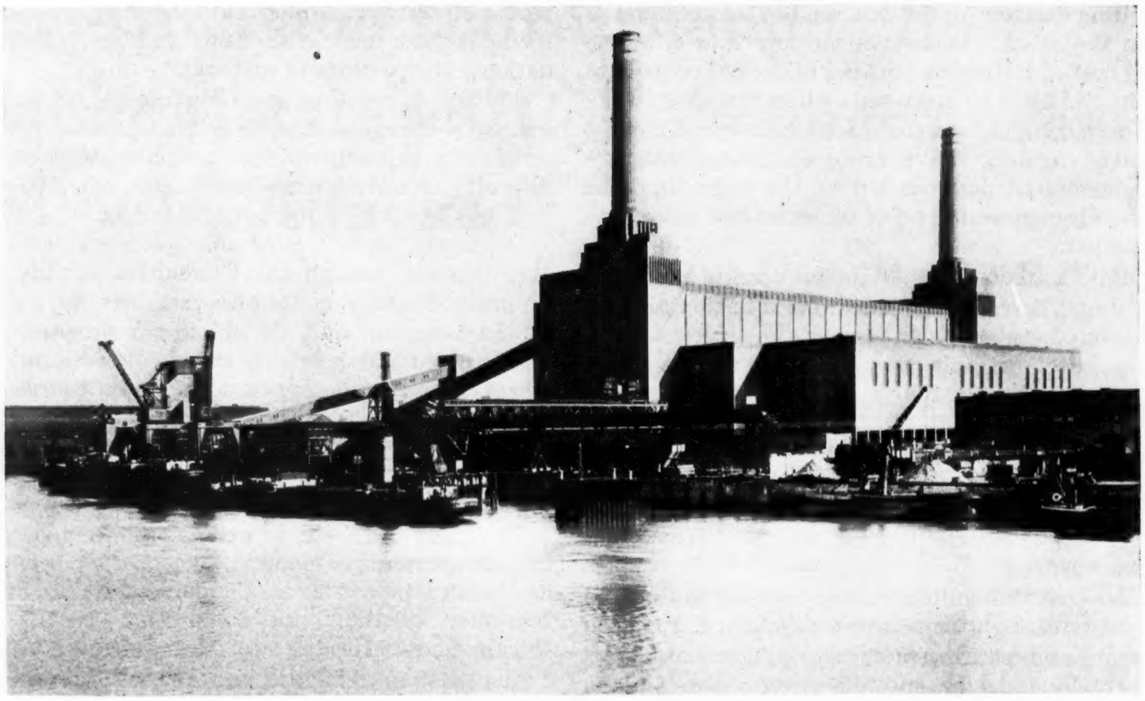
Obviously, such a program would involve considerable expense, though the Committee already has the promises of many of its own members for cooperation in the program, and the minimum program outlined above could not be started without assurance of sufficient interest and support to make its completion certain. That the American and British Joint Committees independently laid out three-year programs is evidence that all investigators realize that sustained effort is required for progress.

Designers and users, as well as producers, of alloys for high-temperature equipment, such as the power plant, oil and furnace industries are therefore invited to inform the Secretary of the Joint Committee, N. L. Mochel, Westinghouse Electric & Manufacturing Company, Lester Station, Philadelphia, Pa. whether they would like to see such a correlation program taken up by the Joint Committee. The Committee desires to be as responsive to the wishes of the interested engineering industries as the available financial resources will allow.

While its own membership feels that the project outlined should be undertaken at the earliest feasible moment, before committing itself to a "three-year plan," it seeks comment and guidance on the selection of this or alternate activities that may be deemed more pressing by the engineering world. The Committee will not assume, in the absence of either adverse or favorable comment that "silence gives consent." Should the program not be sufficiently welcome to the industries concerned so that a definite desire for its pursual is registered with the Committee, the project will not go forward. Comments are therefore earnestly requested, whether pro or con. The comments will be considered at an early meeting of the Committee.

The Bristol Company, Waterbury, Conn., announces that in order to serve the Canadian market better and to expand and consolidate its present Canadian service laboratory of 12 years' standing so as to include sales, service and manufacturing, a separate company, *The Bristol Company of Canada, Ltd.*, has been incorporated. Factory and general headquarters will be located at 64 Princess Street, Toronto, Ont., where recording, indicating and control instruments will be made. J. S. Mayberry has been appointed manager.

S. M. D. Clapper was elected President of the General Refractories Company on January 8, succeeding John R. Sproul, who resigned. Mr. Clapper had been Chairman of the Board of the Company, which post is now vacated. Mr. Sproul also resigned as a Director of the Company and was appointed Assistant to the President.



Battersea Station from River Thames
The gas-washing system extends the full length of the plant between the stacks which are carried on the gas-washing towers

Removal of Sulphur Compounds from Stack Gases in Great Britain

By DAVID BROWNLIE, London, England

The author reviews what is being done in Great Britain in the removal of dust and sulphur from the products of combustion and describes the systems employed in three of the latest stations. Certain limitations of the large water-spraying system, as employed at Battersea, are discussed, as is also scrubbing the gases with milk of lime which is now being carried on experimentally at another Station. The present trend of practice in Great Britain is toward the employment of high stacks.

THE completely innocuous stack top with almost complete freedom from smoke, dust and acid sulphur compounds is now one of the major problems of power-station practice in Great Britain. Many power stations throughout the world are, of course, equipped with dust elimination equipment functioning on one of three general principles, namely, centrifugal, water scrubbing and electrostatic. In Great Britain, however, following upon the lawsuits between the Farmers Federation and the Manchester Corporation in connection with the Barton power station, the matter has advanced a stage further and three power stations are now equipped, or in course of being equipped, to remove over 90 per cent of the total sulphur compounds.

At the new Battersea Station, London, the first section of which with 160,000 kw capacity was recently completed, the combustion gases are sprayed by water in the presence of iron as a catalyst, with a final treatment by means of lime or chalk, dissolved as well as suspended in water. The initial cost of this system was equivalent to $1,250,000. The Fulham Station, London, the first section of which is now in course of erection, for completion in 1935, is also being provided with a water-scrubbing plant. The details, however, have not yet been given out. Another station, in the North of England, has one boiler equipped with a system in which the combustion gases are scrubbed with lime to remove all the sulphur as calcium sulphate, sulphite, thiosulphite and other salts.

Incidentally, a ridiculous degree of secrecy has been maintained in Great Britain during the past two or three years on the subject of the removal of acid sulphur compounds from stack gases. For example, despite all that has been published concerning Battersea Station nothing has yet been made public concerning the net

cost of operating the gas-scrubbing plant. Furthermore, many of the references in the press to Battersea are somewhat confusing and ill-informed, largely due to the incomplete information that has been released from time to time.

The latest and most important paper on the subject is "Application to the Battersea Power Station of Researches into the Elimination of Noxious Constituents from Flue Gases and the Treatment of the Resulting Effluents," by J. W. Hewson, S. L. Pearce, A. Pollitt and R. L. Rees. Dr. S. L. Pearce is the Chief Engineer of the London Power Company, which owns the Battersea Station, and other power stations in London. This paper was read in July 1933 before the Chemical Engineering Group of the Society of Chemical Industry at a meeting held in Newcastle-on-Tyne.

It will be recalled that the principle adopted at Battersea is to scrub the whole of the combustion gases with about 20 tons of water per ton of coal burned together with final treatment by means of chalk or lime, apparently corresponding to about 10 to 12 lb of the alkali per ton of coal burned. These figures are on the assumption that the coal does not contain more than 1 per cent sulphur. The presence of iron as a catalyst is to assist the rapid conversion of the sulphur dioxide into readily soluble sulphur trioxide, which action is aided by the fact that the scrubbing water becomes warm. One of the main discoveries in the research work carried out by the London Power Company was that warm water at say 160 to 170 F is much more effective than cold water; also that the dust particles apparently act as a catalyst in addition to the iron.

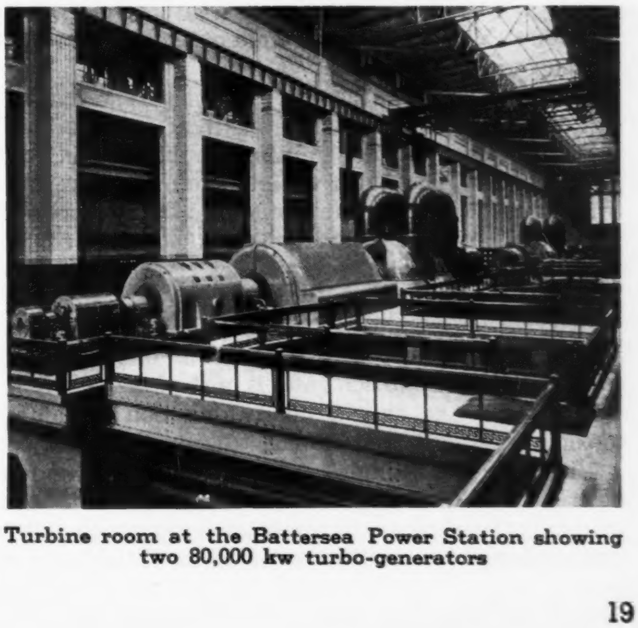
Battersea is also equipped to add a certain amount of heated air or flue gas to the water-saturated combustion gases after scrubbing, with the object of preventing the local deposition of rain round the top of the stack. This, of course, is one of the inherent and serious disadvantages of scrubbing with water, both for removing acid sulphur compounds and dust, since a vast volume of water-saturated gases appearing over the top of the stack and striking a strata of colder air is likely to cause local condensation. Thus at the Battersea power station, even when operating at low load there is a great cloud of "steam" from the top of the stacks. This in itself is not of much importance providing there is no appreciable deposition of rain.

There are now installed at Battersea six boilers fired by multiple-retort stokers, and two 80,000-kw turbine-generators, while an additional unit of 105,000 kw, is on order. The boilers operate at 650 lb and 875 to 900 F steam temperature, with a normal rating of 250,000 lb evaporation per hr, 312,000 lb maximum continuous rating, and 330,000 lb peak load. Each boiler on peak load burns 19 tons of coal per hr. Eventually this section of the station will contain nine boilers, of which two are intended as standby. Thus the total coal consumption during normal operation will be 133 tons per hr. This will correspond to about 66,000,000 to 80,000,000 cu ft of gas per hr, and it is stated that the concentration of sulphur dioxide (SO_2) is 0.02 to 0.05 per cent in the gas when burning coal containing 0.80 to 1.0 per cent sulphur which, incidentally, is much below the average for British coal.

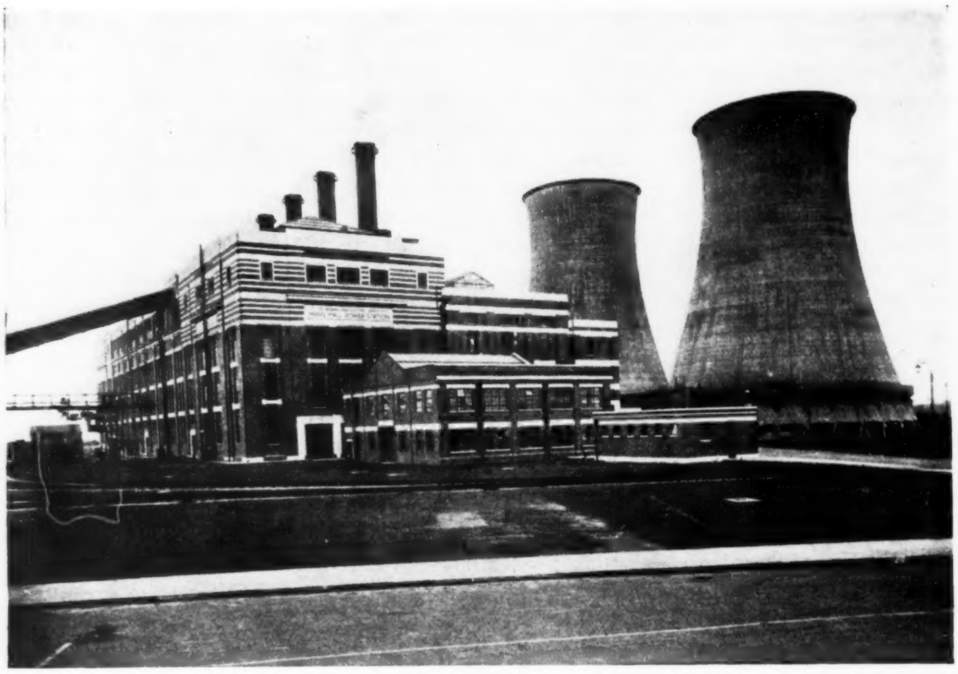
Each boiler has four induced-draft fans, each with a centrifugal dust separator on its suction, thus making a total of 24 fans. The boilers all discharge, by way of small primary chambers containing pressure water sprays, into a vast overhead horizontal saturation and scrubbing flue. This flue extends the whole length of the station between the two stacks, situated one at each end, and is 475 ft long, 38 ft high, and 23 ft wide, with a cross-section of 874 sq ft. In this scrubbing flue is a series of high-pressure water sprays, and at each end the flue leads into two huge vertical concrete scrubbing towers which are over 160 ft high and divided vertically into three compartments. The combustion gas from each end of the horizontal flue enters at the upper portion of the vertical towers and passes down through the center compartment, which contains four banks of sprays. At the bottom the gases in each of these vertical flues divide into two, each half of the volume passing up through the two outer compartments, containing additional banks of sprays. Also, there is an alkali scrubber on the top of the towers, with warm air inlets to the two concrete chimneys, which are fixed at the top of the towers, representing a total height from the ground of 335 ft 6 in.

As already indicated, the net capital cost of the flue gas treatment system is given as over $1,250,000, but this does not include the twenty-four centrifugal separators on the six boilers, nor has there been any reference in the published accounts to the operating costs involved in the pumping of the 40,000 tons of water per day that will be required on full duty. In fact the total gas treatment plant, including the arrangements for mixing the lime and treating the sludge before discharging to the Thames, seems to be about half the size of the power station. Further information on this subject will be awaited with the greatest interest. Some of the troubles, however, that might be expected would be the deposition of solid material from the sludge, stoppages in the vast number of spray nozzles, and, particularly, corrosion of the materials used for the construction, irrespective of the question of the power consumption and the local deposition of rain, already mentioned.

The new Fulham power station in London, also on the Thames, and belonging to the Fulham Borough Council, is designed for an ultimate capacity of 318,000 kw.



Turbine room at the Battersea Power Station showing two 80,000 kw turbo-generators



Hams Hall Power Station, Birmingham

The short steel chimneys are to be replaced by one high concrete chimney operating in conjunction with an electrostatic dust separation plant

The first section, now in course of erection, will include six water-tube boilers operating at 625 lb and 850 F steam temperature. The normal evaporation for each boiler will be 260,000 lb per hr and they will supply steam to two 60,000 kw turbine-generators. They will be fired by multiple-retort stokers, and equipped with economizers, air preheaters, forced- and induced-draft fans, steel-tube, water-cooled combustion chamber walls and two concrete stacks, 300 ft high.

In this connection it should be pointed out that because of the troubles with dust and acid sulphur compounds there is now a pronounced tendency in British power-station practice to go back to the high stack, say 300 to 350 ft. The recent report of the Electricity Commissioners in Great Britain on the subject of nuisances caused by waste combustion gases emphasizes that stacks should be at least two and one half times as high as the top of the power station buildings.

At one of the latest power stations in Lancashire it is understood that considerable trouble is being had from corrosion of the new steel stacks, while at the Barton station in Manchester two very large concrete stacks, over 300 ft high and 18 ft in diam at the top, are to be erected to replace the steel stacks.

The exact nature of the water-scrubbing plant at Fulham, as previously mentioned, has not been disclosed, but it is stated that the Fulham Borough Council has been operating one boiler experimentally for over two years at another of its plants, and that over 90 per cent of the total sulphur compounds can be removed, apparently also with a large proportion of the dust. The general figures claimed at Battersea, and elsewhere, are 90 to 95 per cent removal of the acid sulphur compounds, while apparently also over 95 per cent of the sulphur present in the combustion gases is in the form of sulphur dioxide (SO_2) and only a small proportion as sulphur trioxide (SO_3), although opinions differ on this subject.

With regard to the third station in Great Britain now experimenting on a large scale, the principle consists in scrubbing the whole of the combustion gases with milk of lime, under which conditions it is claimed that over 90 per cent of the total sulphur in the gases can be removed with a total volume of water amounting to only 0.85 to 1.30 tons per ton of coal burned, based on the usual assumption of about 1 per cent sulphur in the coal. The amount of lime necessary is given as approximately 1½ tons for each one ton of sulphur in the coal.

While the acid sulphur compounds in combustion gases can be removed by direct scrubbing with strong alkali solutions, such as caustic soda, sodium carbonate, lime or chalk, the cost involved would be enormous when using caustic soda or sodium carbonate, while one finds it difficult to understand how even the use of lime can be regarded as a practical proposition. Thus, for example, a power station burning 2000 tons of coal per day would use 45 tons of live lime in this time, all of which has to be handled and slaked. This is a formidable undertaking, quite apart from the cost of the lime, while even more serious would seem to be the fact that at least 200 tons of sludge per day would be produced, all of which must be disposed of in some manner.

Under these circumstances, the power station staff would, in effect, have to take on the operation of a chemical works, especially as there is some talk of endeavoring to recover sulphur from the calcium sulphite and perhaps calcium thiosulphite. The main claim, however, is that by using lime cream in this way only a relatively small bulk of liquor has to be handled, while if care is taken to keep the mixture always alkaline there is immediate and effective separation of the calcium salts in the form of a heavy sludge. This leaves a clear liquor that may discharge to streams or sewers. Again, no information has been developed as to the net operating costs.

In connection also with the innocuous chimney top as regards dust elimination, it is interesting to note that the Birmingham Corporation has now decided to install Lodge-Cottrell electrostatic dust separation equipment at both the Hams Hall and the Nechells power stations. The latter is a comparatively old plant, partly equipped with pulverized-coal firing and partly with mechanical stokers, while Hams Hall is one of the newer and more

important British stations, running entirely on pulverized coal of low-grade, relatively high ash content.

At Hams Hall the five existing boilers each have a maximum evaporation of 228,000 lb of water per hr, and the electrostatic plant is to be capable of dealing with 880,000 cu ft of gases per min at an average temperature of 315 F. This system will serve the five existing boilers and two new 300,000-lb boilers that are to be installed. Also, a new stack 350 ft high is to be erected. The electrostatic plant is guaranteed to remove 92 per cent of the total dust, of which 50 to 70 per cent are below 10 microns in size.

At the Nechells station the electrostatic plant will deal with 396,000 cu ft of gas per min at 388 F from four pulverized-coal-fired boilers, each of 180,000 lb per hr normal evaporative capacity. In this case 90 per cent of the dust is to be removed, while as before a new stack, 350 ft high, is to be erected.

Over one hundred power stations in Great Britain are now equipped with dust removal systems. These operate mostly on the centrifugal principle, but considerable interest is now being shown in the electrostatic method, which is operating at the Willesden station in London and also upon a number of plants on the Continent of Europe, particularly Germany and Belgium.

In the opinion of the Electricity Commissioners, as expressed in their report, this is the best method for separating dust particles from combustion gases when pulverized fuel firing is used, since uniform efficiency is obtained without regard to the size of the particles. With regard, however, to the combined separation of dust and acid sulphur compounds the matter is extremely complicated, and much more large-scale experience will be required before any very definite opinions can be expressed.

In this connection the highly important work that is being carried out by Prof. H. F. Johnstone[1] at the University of Illinois on the removal of sulphur compounds from waste gases is being watched closely in Great Britain.

[1] See Combustion August 1933, p. 19.

E. M. Gilbert Engineering Corp. New Name for W. S. Barstow & Co.

The name of W. S. Barstow & Co., Inc., has been changed to E. M. Gilbert Engineering Corporation, according to announcements just received from the Company's headquarters at Reading, Pa. The new name was voted at a recent meeting of the board of directors to identify the organization with its president, E. M. Gilbert. Vice Presidents of the company are A. P. Campbell, J. A. Powell and R. L. Baker.

W. S. Barstow & Co. was incorporated in 1906 to function as a centralized engineering, construction and management company for various utility companies. For many years the corporation has not only acted as engineers and constructors for new utility power plants and transmission systems, but has also acted in a general consulting capacity in a wide variety of construction and operating problems. During the past five years it has provided engineering service and supervised construction involving utility company expenditures of approximately $80,000,000.

F. M. Feiker Becomes Secretary of American Engineering Council

Frederick M. Feiker, until a few months ago Director of the Bureau of Foreign and Domestic Commerce of the U. S. Department of Commerce, has been chosen as Executive Secretary of American Engineering Council to succeed L. W. Wallace who recently resigned to become Vice President and Washington representative of the W. S. Lee Engineering Corporation.

Mr. Feiker graduated in electrical engineering from Worcester Polytechnic Institute in 1904 and, after a number of years in various editorial capacities, became Vice President and editorial director of the McGraw-Hill Publishing Company. He resigned to become Vice President of the Society for Electrical Development and later was appointed managing director of the Associated Business Paper, Inc. In the interval between the relinquishment of his governmental duties and his present appointment, Mr. Feiker was engaged in making a survey of the needs and methods of developing trained men for the textile industry under a grant from the Textile Foundation. He has long been an active member of both the American Society of Mechanical Engineers and the American Institute of Electrical Engineers.

With this background of experience and the contacts with official Washington, obtained while Director of Foreign and Domestic Commerce, Mr. Feiker is well qualified to carry on effectively the work of American Engineering Council.

Obituaries

Joseph S. Oechsle, a consulting engineer of the Worthington Pump and Machinery Corporation, died at the Hahnemann Hospital in Philadelphia on December 24, 1933, at the age of 39. Mr. Oechsle was one of the founders and subsequently President of Metalweld Incorporated, of Philadelphia, manufacturers of portable air compressors, before that company was consolidated with Worthington in 1931.

L. E. Pollard, representative of the Atlas Engineering Company in Pittsburgh, and at one time representative of Combustion Engineering Corporation in the Minneapolis, St. Paul territory, died late in November of heart disease.

Louis B. Nutting, President of the Foster Wheeler Corporation, died at his home in New York City on January 12. He was 63 years old. Born in Lansing, Minn., Mr. Nutting's early years were spent in the wheat belt and in 1893 he joined the organization of Henry R. Worthington, leaving three years later to become associated with R. D. Wood & Company, hydraulic equipment manufacturer of Philadelphia. In 1903 the Power Specialty Company was organized and he became General Sales Manager, and later President. He organized the Foster Marine Boiler Corporation following the War, became its President and was instrumental in bringing about the consolidation of the Power Specialty Company and the Wheeler Condenser and Engineering Company under the name of the Foster Wheeler Corporation of which he became President.

Manufacture and Marketing of Steam in Manhattan*

A review of over fifty years of progress in furnishing central steam supply to the buildings of Manhattan. Load conditions, boiler design and operation, as influenced by the character of service, are discussed and the distribution system described. This service is supplied by three steam-generating stations having a combined capacity of 4,900,000 lb of steam per hr, through sixty miles of mains, to the up-town and mid-town sections of the city.

By A. R. MUMFORD
Research and Design Engineer
New York Steam Corporation

Early History

ON MARCH 3, 1882, the New York Steam Company, the predecessor of the New York Steam Corporation, started supplying steam to its first customer, the United Bank Building at 88–92 Broadway. This operation marked the actual beginning of the largest public utility in the world engaged solely in the manufacture and sale of steam. In that first year service was rendered to sixty-two customers, many of whom used the steam for the principal existing power requirement, elevators and pumps. In the early history of the business the names of two individuals are frequently mentioned, Wallace C. Andrews, the financier, and Charles E. Emery, the engineer.

The Company's first boiler plant, located on a plot bounded by Cortlandt, Dey, Greenwich and Washington Streets, was erected in 1881 and contained forty-eight 250 hp boilers arranged so that sixteen were on each of three floors with space left on a fourth floor for future capacity expansion. The boilers were, of course, fired by hand. The original plant still produced steam for distribution as late as 1924. The site is now used for a garage and radio stores.

During the first year the distribution system grew to a length of three miles, and steam, at 80 lb, was distributed for power, cooking and heating. Meters had to be, and were, developed for the measurement of the product; expansion and contraction had to be absorbed in an inaccessible crowded line; pipe joints had to be developed; and, to mention only one other problem, steam condensate return over long distances had to be tried and later abandoned.

* Excerpts from a paper before the Brooklyn Engineers' Club, Jan. 11, 1934, printed by permission of that club.

Later History

Mr. Andrews met his death tragically in a fire at his home at the turn of the century leaving in his will provision for an endowment for the establishment of a girls school in Ohio. Because his funds were largely in the New York Steam Company the school became the owner of the utility. Litigation and conditions of ownership increased greatly the difficulties of arranging proper financing for the expansion of the business until 1921 when the Company was bought out of receivership and became the New York Steam Corporation. The changes in the financial basis and restrictions made it possible for the Corporation to expand when the building boom of the last decade made it advisable to expand and thus to enjoy a period of almost spectacular growth. The annual sales of steam increased over eight billion pounds or 375 per cent in the calendar year 1932 over the calendar year 1922. The probability of rapid expansion in the forthcoming years is dependant on the resumption of building and is, of course, too hazardous to forecast.

The length of pipe making up the mains and services through which steam is distributed increased from about 148,000 ft in 1922 to about 378,000 ft in 1932 or an increase of about 155 per cent. It is apparent that the concentration of steam sales, that is the sales per foot of main, has increased in the same period because the percentage increase in sales is over twice that in length of mains. That this condition is desirable is obvious from a consideration of the rate of return on main investment.

Formerly there were two separate districts; one uptown, centering about the Grand Central area; and the other downtown, in the financial district. Recently these two districts have been connected with a feeder main. This connection improves the situation from the standpoint of generation inasmuch as somewhat less total spare capacity need be provided.

The contents of buildings served shows the greatest proportionate increase of the factors discussed thus far. The year 1932 showed service to about 2,300,000,000 cu ft of buildings an increase of about 475 per cent over the volume served in 1922. The increased use of tower construction is again reflected in the relative increase in volume as compared to mains and services. The relative increase of volume served to steam sold is an indication of more efficient use probably partly due to a decrease in the ratio of wall area to volume which occurs in tower buildings and partly to the decreasing proportion of steam used for power services.

Production of Steam

In the central-steam industry the nearness of the generating station to the market is of great importance as compared with the electric industry because of the nature of the product and the cost of transportation lines. For this reason the stations of the New York Steam Corporation are located near the uptown and the downtown centers.

A plentiful supply of good water is available from the municipal mains and the only problem is to connect with the city network in such a manner that the greatest assurance of continued supply is obtained. This assurance is obtained by providing at least two water-service connections either one of which has sufficient capacity to supply the maximum expected demand. These service connections tap the city network at points separated physically by a reasonable distance and separated mechanically by valves in such manner that a break in one supply can have only a minor temporary influence on the other. Coal supply influences the selection of a site only on the basis of transportation facilities and cost. Truck transportation of several thousand tons of coal per day on Manhattan's congested thoroughfares is out of the question physically, economically and from the standpoint of civic pride. It is therefore apparent that the harbor facilities must be used and the site on the waterfront chosen.

Load Curve

The seasonal nature of the central-steam industry is clearly shown by the load duration curve. The first tenth of the peak demand exists for the whole year but the last tenth exists for only one two-hundredth of the year. This short duration of peak demand is, of course, due to the temperature. The principal interest of the load curve is the emphasis it places on the capacity phase of the design and operation of the steam-generating units for the top portions of the peak demand. Considered separately from the remainder of the load, the last fifth of the peak demand, used for one-fortieth of the year must earn enough to carry its portion of the investment for the whole year. This is, of course, impossible because the crudest and simplest installation would necessitate too great a charge per unit of production. It has, therefore, been necessary in the design of the generating units to carry both efficiency and capacity to justifiable limits and to depend on the increased efficiency at normal demands to carry the peak capacity charges.

Design

The proportioning of the heating surfaces, the protection of brickwork, and the application of auxiliary power are some of the factors which we have endeavored to combine in our newest units in order that they should be capable of high rates of production at high efficiencies.

In the proportioning of heating surfaces the fact that the last two-thirds of the normal boiler surface contributes only about one-fourth of the total work has been recognized. If the last part of the boiler heating surface was removed the total work would not be greatly diminished and a higher temperature head would be available for heating the feedwater. Such an increased temperature head is valuable for feedwater heating in economizers under conditions of high proportionate makeup as in the central-steam industry which has no

Skyline of lower Manhattan in the early eighties when stacks of New York Steam Company competed with Trinity Church spire

condensate returns except from plant auxiliaries. The same reasoning was applied to the economizer surface and it was limited to the area before that point at which the rate of heat transmission became too "lazy" to support the charges. This again left a good temperature head available for heating the air to be supplied for combustion.

In the following table the areas of the parts of the heating surface are given for each of the five boilers at the Kips Bay Station at 35th Street and East River, together with the maximum sustained rate of steam generation.

TABLE I—PROPORTION OF HEATING SURFACES

Boiler No.	1, 2 & 3		4		5	
Type of surface	Area	Per cent	Area	Per cent	Area	Per cent
Furnace walls, sq ft	4132	13.9	3954	12.7	8250	13.3
Boiler, sq ft	15380	51.9	16950	54.7	34260	55.1
Economizer, sq ft	10080	34.2	10080	32.6	19656	31.6
Total water cooled, sq ft	29592	100.0	30984	100.0	62166	100.0
Air heater, sq ft	64800	...	46800	...	61440	...
Max. sustained evap., lb hr	370000		450000		950000	
Evap sq ft boiler and furnace sur. lb/hr	19.0		21.5		22.2	

The elimination of "lazy" boiler surface is of no significance unless the capital charges at equal efficiency are less than in the boiler of more nearly normal proportions. At this time the boiler designer is in control of the amount of surface which can be eliminated from a boiler because he cannot guarantee the production of dry steam unless the cross-sectional area of the drum bears a fixed relation to the quantity of water evaporated. Because this stipulation fixes the drum size for a given capacity and because the cost of the drums is the major part of the boiler cost the limits to which a plant designer may go in proportioning heating surface are narrowed.

With the proportions of heating surface shown, the efficiencies under operating conditions at the relatively high capacities are held consistently between the limits of 83 and 86 per cent. In this manner the Corporation has attempted to meet the demands of a difficult load curve with equipment designed for high efficiency at maximum sustained loads.

Physical Plant

Of the capacity of 4,900,000 lb of steam per hr obtainable from our own stations 2,450,000 lb or 50 per cent, is generated from bituminous coal burned in pulverized form; 2,250,000 lb, or about 46 per cent, from small-sized anthracite burned on chain-grate stokers; and

200,000 lb, or 4 per cent, from bituminous coal burned on underfeed stokers.

The plant which burns bituminous coal in the pulverized form is the Kips Bay Station located at 35th Street and the East River. This plant is on a site capable of supporting considerably greater capacity than is at present installed. The five boilers now installed range in capacity from 370,000 lb per hr for the three oldest installed in 1926 to 950,000 lb per hr for the fifth installed in 1930.

Of the two anthracite-burning stations that located in the downtown area in Burling Slip has a capacity of 1,800,000 lb of steam per hr from fourteen boilers. Twelve of the boilers were installed in 1916 with a capacity of about 700,000 lb of steam per hr which was doubled in 1924 by remodeling the furnaces and baffling and adding economizers and fans. The remaining 400,000 lb capacity was installed in 1929 with provision for expansion which may now prove unnecessary because of the interconnection of the districts.

The uptown anthracite-burning station at 59th Street and the East River was remodeled in 1921 and had a capacity of about 350,000 lb of steam per hr from these boilers. The furnaces were altered in 1930 to increase the capacity of this plant about 20 per cent.

The stoker-fired bituminous coal burning plant was built in 1907 opposite the present anthracite burning plant uptown. A capacity of about 200,000 lb per hr is obtained from five boilers in this station.

The amount of coal burned annually to produce the steam sold in Manhattan is about 817,000 net tons, enough to heat 82,000 average homes. The amount of steam made is 14.6 billion pounds which, the statisticians figure, is enough in the form of water to form a circular lake one mile in diameter with an average depth of 10 ft.

Return of Condensate

Considering the cost of water and that the condensate contains almost no dissolved solids it is pertinent to ask why are not steps taken to return the condensate to the generating stations. The answer is that it costs more to return the condensate than to buy fresh water and treat it. When Emery designed the first New York system he made provision for the return of the condensate but the maintenance of the lines was found to be so costly that the return was abandoned. Naturally the use of raw cold water instead of hot condensate as used by the isolated plants placed a competitive burden on the utility. This burden has been reduced by the installation of heat-recovery apparatus on the consumers premises which not only provides a source of hot service water for the consumer, but also cools the condensate to a temperature at which it is legal to discharge it to the sewer.

Distribution of Steam

The New York Steam Corporation and its predecessor have installed about sixty miles of steam mains under the pavements of Manhattan. These mains pass over subways; under street car tracks; over the New York Central Railroad lines in Park Avenue; and over, under or around telephone, telegraph, light and power cables, sewers, water and gas lines. The design, installation and operation of these services require engineering skill of a high order and engineering experience of a specialized nature.

The general layout may be called the gridiron system composed of trunk feeders extending west from the plants and connecting with other feeders running north and south in the avenues. Within the spaces enclosed by large mains, smaller lines are run east and west connecting to the feeders at both ends where possible and including provision for service connections.

The pressure equipment used in transporting steam has developed through fifty years of experience into the type now used for dependable service. The pipe is lap-welded steel designed in accordance with the accepted standards for 250 lb pressure. The pipe is made up in standard lengths and the flanges are welded to each length in the fabricating shop. Of course, special lengths and bends are used where necessary. Fittings are of cast iron. All main valves are built with stationary stems because the depth of excavation and the cost would be much greater if rising stems were used. Expansion joints of corrugated copper are installed in the line on both sides of a cast-iron anchor fitting at intervals of about 150 ft. The service fitting is cast iron, T-shaped, with the side service outlet at or above the centerline so that any condensate at the bottom of the main will not be discharged through the service connection. Condensate is removed from the bottom of the main at low points in the run provided for in the design. Provisions for service outlets are provided at about 75-ft intervals along the length of a run.

With a clear graded trench prepared, a reinforced concrete base is laid between manholes. On saddles on this base the steel main as large as 24 in. in diam is laid. The pipe is insulated with formed magnesia block, canvas covered. A tarred felt paper is wired on outside of this insulation to reduce the amount of water absorbed by the magnesia in the event of a break in adjacent water mains. Between the main and the concrete base hollow tile is placed to provide drainage of surface waters, etc. to the low point of the housing. The sidewalls of the housing are next constructed of hollow tile closed at the ends and covered after erection with a layer of cement. The remaining space is filled with mineral wool before the reinforced concrete cap is poured. At the frequent manholes the surface or flood waters are drained to the sewer if the sewer is low enough or pumped by automatic sump pumps if the drainage point is below the sewer level.

Where mains are installed at levels low enough to be submerged at high tide or where insufficient space is available for the concrete and tile conduit a cast-iron conduit is used. The cast-iron conduit is made in standard lengths split horizontally into a bottom half of square section and a top half of semicircular section. Caulking lips are provided at the end and longitudinal seams for lead caulking thus providing a water-tight construction.

The drainage of the condensate formed within the main is accomplished in a unique manner. It is obvious that the additional excavation necessary to place trap stations below the level of the main would be expensive and the manholes much larger than if the traps were installed above the main. The pressure on the designers to provide for the internal drainage under the conditions of extreme congestion existing in subsurface Manhattan led to the development of the overhead trap system. The condensate is drained from the bottom of the main at the low point into a U fitting which discharges verti-

cally upward to a pair of float-controlled traps located vertically above the main. The trap discharge is cooled by radiators in an air-cooled manhole to the legal temperature for discharge to the sewer. This construction permits the condensate traps to be located in easily accessible shallow manholes at a fraction of the cost that traps below the mains would involve.

Ventilation of manholes which reach a temperature nearly as high as that of the steam is accomplished by providing a small side manhole connected to the main manhole by a duct through which cooling air can circulate. This construction has shortened the time the inspection crew must wait before descending to the main level.

Operation

The operation and maintenance of these hidden pipes involves the holding of crews of men and equipment at strategic points ready to isolate any part of the system endangered by fire, construction cave-ins, etc. The operation starts with the initial turn-on when, because of the cold pipes, condensation is rapid and great care must be exercised to prevent the accumulation of large quantities of water. Thereafter, except for accident, normal operation consists of opening and closing supply valves, routine inspection and maintenance of traps and sump pumps, and the maintenance of the desired distribution pressures by calling for and controlling the supply from the several sources. The proper coordination of available and desired supply to the end that each source of steam shall be economically loaded requires the routing of steam by means of throttling valves on the several main lines. This function of controlling the direction of the flow of steam is part of the load despatching activities of distribution operation.

Several points, remote from the generating stations, are selected as constant pressure points in the distribution system. At these points special pressure gages are installed which transmit electrically an indication of the pressure which is used for control of the supply. Under this system the pressure at the station is raised, as the demand for steam increases, enough to force through the mains the quantity of steam necessary to maintain the pressure at the remote point.

A few of the new and larger buildings served are:

Empire State Building	The Tudor City Group
Chrysler Building	Chase National Bank Bldg.
Lincoln Building	Hotel Pierre
City Bank Farmers Trust Bldg.	Majestic Hotel
Bank of Manhattan Building	Sherry Netherland Hotel
Irving Trust Building (1 Wall St.)	Savoy Plaza Hotel
Salmon Tower Building	Park Central Hotel
Chanin Building	Barbison Plaza Hotel
Daily News Building	Lincoln Hotel
The French Building	Manger Hotel
Fuller Building	Ambassador Hotel
10 East 40th Street	

All of the New York Central Railroad group from 42nd to 50th Streets and Lexington to Madison Avenues, including the Hotels Commodore, Biltmore and Roosevelt and all station terminal and office buildings, are supplied, as is also the new Waldorf Astoria Hotel.

Rates

The cost of service and stability of rates is assured by the fact that steam is sold entirely on a meter basis under rules and regulations approved by the Public Service Commission.

Without any precedent to follow the rates have necessarily been a gradual development in the endeavor to fix the charges on an equitable basis. It has been necessary to take into consideration three elements of costs, namely, consumer costs, demand costs and quantity costs. Consumer costs, made up of such items as meter maintenance, equipment inspection, billing, etc., are incurred in almost direct proportion to the number of consumers. Demand, or readiness-to-serve costs, are those capital and operating costs that are necessary to provide sufficient plant on the line to be ready to serve every consumer at the time service is desired. Quantity of service costs are made up principally of production costs after omitting a portion of costs which are necessitated by the demand element.

In order that consumer costs may be collected, each of the rates carries with it a minimum bill and charges which are graduated downward. Having segregated the consumers into rates wherein the annual load factors of the consumers within each rate do not radically depart from the average of such rate, we have been enabled to allocate and collect the proper amount of costs occasioned by the demand element. This has been done in two ways; first by designing the rate classifications in such manner that the average monthly charge per thousand pounds of steam, with an infinity of use, will vary depending upon the average annual load factor; and second, in the General Service Rate, which includes many small users of steam, it was found that the annual load factor tends to improve with larger quantity use so that it was necessary to graduate the charges to take care of demand costs as well as consumer costs. The quantity costs are proportional to the use and no special explanation seems necessary to cover the method of including them in the rate structure.

From the beginning of over fifty years ago the growth of the Steam Corporation business was not sensational until about 1923 when a building boom started and when the Corporation's financial structure had been reorganized. The rapid increase in the number of tower buildings and the higher standards of comfort and cleanliness increased the economy of and demand for utility steam service. Existing plants, representing an investment which must be carried, restrict our competition to operating costs unless the demand for space is great enough to warrant remodeling the basement into rentable area. At the present time the difficulty of obtaining capital, or money for major maintenance items, is of assistance to us in obtaining customers whose equipment is in difficulties. The use of steam for air cooling and conditioning will, if extensively adopted, greatly improve the annual load factor. The resumption of building and, in Manhattan, modernization will again be accompanied by a rapid growth of the steam utility.

M. S. Ketchum, Dean of Engineering and Director of the Engineering Experiment Station at the University of Illinois has, at his own request, been relieved of these duties and has been made research professor of civil engineering at that university. In this capacity he will continue research investigations and graduate instruction.

Colloids in Boiler-Water Conditioning

By HENRY T. HOTCHKISS, Jr.

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Recent issues of COMBUSTION have devoted considerable space to the subject of feedwater treatment. One phase of the subject concerning which there is division of opinion and which appears to have been dealt with more fully in scientific papers than in the engineering press, is colloidal treatment. The author discusses the colloidal theory in some detail and points out that the laws which apply to the body of a solution and control homogeneous equilibria, as affecting other forms of feedwater treatment, do not apply to surface phenomena which he contends is appreciable to colloids because of the vast dispersion of micronic particles.

ANY material introduced into a boiler for the purpose of controlling impurities in the water must meet the following criteria:

1. It must be harmless. It must not attack the boiler metal or valves, fittings, pump packings, etc. with which it comes in contact, and its use must not develop any secondary effects that might be harmful.
2. Since there is a wide variation in the amount and nature of impurities present in boiler waters, the action of the added material should be specific in regard to the impurities.
3. The amount of material added should be a minimum in order to control the interdependent factors of concentration and blowdown.
4. The material should have no deleterious effect on the purity of the steam passing to prime movers or to processing equipment. This factor cannot be overlooked in steam turbine practice, in the dyeing of fabrics or in the preparation of food by live steam.
5. From a practical standpoint, the substance should be economical in use.
6. Boiler temperatures and pressures should not affect the material, and the methods of control and introduction in use should be simple.

The class of solids in suspension may be represented by milk of lime. The theory behind the old practice of adding lime is that a thin scale is formed over the metallic heating surfaces and thus prevents corrosion. This is a case of substituting one difficulty for another. Cases are not uncommon where sub-scale corrosion has taken place.[1]

The use of chemicals in solution to control the harmful impurities in water is widely practiced. This is based on the principles of acid-base neutralization, matathetical reaction and solubility. In the case of inorganic substances, the action is covered by the theory of solution governing electrolytes, where the laws of chemical equivalence govern the action.

Certain colloids are used to condition boiler feedwater.[2] Colloids are units of matter in a state of subdivision, having dimensions lying between those of particles in suspension and in true solutions. There is no distinct line of demarcation in the transition from fine suspensions to colloidal dispersions, nor from these to solutions of large molecules. The colloidal state is not limited to either organic or inorganic substances. Theoretical considerations and practical operation have shown that under regulated conditions the introduction of material in a highly dispersed condition permits the utilization of physical properties concomitant with surface phenomena—adsorption, absorption and electro-physical polarization. It is proposed to explore this subject in some detail.

The attempt to treat colloidal or capillary functions by ordinary stoichiometrical relationships leads to erroneous conclusions.[3] That division of physical science, known as colloid chemistry, grew out of the recognition of this fact. Electrochemical and electrokinetic effects must be differentiated. It may be convenient at times to use formulas and equations in the exposition of the subject, but in no case should the fundamental characteristics of colloidal bodies be lost sight of, namely, the dispersion and the effective surface.

If in the treatment of feedwater the peculiar interfacial phenomena (which do not exist in true solution) are to be utilized to the fullest extent, it is necessary to insure a high dispersion. The relation of surface to volume is not a straight-line function. Thus, if a cube has linear dimensions of one centimeter, the total surface will be six square centimeters, and if this cube is now subdivided so that dimensions of 0.0000001 cm are obtained, the resulting area of surface of these particles will be 60,000,000 sq cm,—equivalent to 1.48 acres. To obtain high dispersions in the laboratory requires care and precision. To produce them in a factory in sufficient quantity for use in industry necessitates involved procedure, complicated processing equipment and scientific control. The elimination of particles which have not reached micronic dimensions is essential, since these particles not only minimize the effective action of the colloids, but also introduce added impurity into the boiler.[4] If this care is not exercised the solid masses may even act as a binder in scale formation. Unfavorable results have followed the indiscriminate use of colloidal materials. This has caused a natural antipathy toward

[1] F. N. Speller "Corrosion—Causes and Prevention" (1926).

[2] See "The Chemistry of Water and Sewage Treatment" (1928), p. 140.

[3] Fruendlich, "Colloid and Capillary Chemistry" 3rd Edition, p. 339, 364, 536 (Hatfield translation).

[4] Tang extracts of extremely low insoluble content can be obtained by proper processing. When one part of the extract is used for 10,000 gal of feedwater and the insoluble content is 0.001 per cent the insoluble content of the feedwater is raised only one part in 1,000,000,000. An insoluble content of 0.001 per cent is technically practical. A product in which 85 per cent of the dispersed material passes an ultra filter (pores 20–100 uu) can be produced.

colloids in general. The positive action of a scientifically selected dispersion, obtained under controlled conditions of manufacture, and from which harmful components have been eliminated, cannot be denied either on the basis of academic theory or technological results.

Adsorption is a surface phenomenon. It is specific and selective. In other words, to remove a particular impurity from a solution, it is necessary to find a specific colloid which will adsorb it. This is a matter of experimentation. The search for colloids which will adsorb impurities from boiler feedwaters has been widespread. The number which have this property and also meet the criteria outlined above is limited. The adsorption of gases, such as oxygen and carbon dioxide; of liquids such as oil; and dissolved solids which contribute to the scale forming properties of a feedwater must be considered. Furthermore, if the dispersed particles are to be effective in the boiler they must not break down under operating conditions of temperature and pressure, with the consequent destruction of the effective surface area of the specific colloid. The fallacy of introducing any colloidal substance into the boiler which undergoes thermal decomposition is evident. Not only is the gel destroyed but the system is contaminated by the products of decomposition.

Approaches True Solution

The homogeneity which results from the proper distribution of a suitably processed dispersoid approaches that of true solution. It may be said without gross exaggeration that the sub-microns distributed throughout the solution will penetrate to any point in the boiler system where water itself will go. Those particles, which may be seen by means of dark field illumination. will be found to show Brownian movement. They are constantly moving in all directions and they may be seen to move in the microscope field as if animated. The field of activity of any particular particle is thus greater than if it were motionless. It has been calculated that the particles actually change their direction 10^{20} times in a second under regulated conditions.[5] This might be termed ultra-Brownian movement.

While steam is being generated, the dissolved materials in the feedwater are concentrating in the boiler. To control this factor, the practice is to blow down a portion of the boiler content from time to time, or continuously. If suspended matter is distributed evenly in the boiler water as in the case of a fine suspension, the amount which is removed during any blowdown period will be directly proportional to the blowdown. If it were possible to concentrate the suspended matter and cause it to settle into the mud drum, a greater proportion of the suspended material could be removed during blowing down. This condition can be induced by the formation of gels in which the solid particles are trapped. These will agglomerate and increase in mass until a definite sedimentation action takes place.

In the process of gel formation, polar adsorption plays a definite and important part. Here the electro-physical properties of the dispersed particles come into play. One of the objects of feedwater treatment is to remove those ions, such as calcium and magnesium which enter into and cause scale formation. These carry a positive charge. If the colloidal bodies introduced into the boiler are of a negative character, electro-neutralization of these charges will take place causing precipitation of that portion of the disperse phase entering into the action. This results in the formation of gel flocs. These flocs are both adsorptive and absorptive. Because of their non-crystalline form, the surface area is still important, and their porous character enables them to pick up and retain other impurities, until such time as the floc becomes heavily laden and settles out.

Protective Colloids

The term "protective" applies to a colloid when it opposes the aggregation of molecules or particles into larger groups.[6] If a colloid of the protector type is introduced into a boiler, its activity becomes apparent from the fact that a concentration of scale forming materials can then be tolerated which would ordinarily be detrimental to the heating surfaces. Scale is composed of interlocking crystals. The protective action of the colloids prevents this interlocking effect. Consequently scale does not form. This power varies widely and a protective colloid must therefore be chosen to suit the condition under which it is to be used. The action may be thought of as the formation of a sheath surrounding the particles.[7] This sheath not only develops where the particles are of crystal-forming dimensions, but also with suspended aggregates of microscopic or macroscopic size. The use of a colloid, possessing this attribute of inhibiting crystal growth and deposition of scale-forming substances, through protective action, is distinctly advantageous in controlling this condition.

No inorganic colloidal material has been found which is suitable for the internal treatment of boiler water. Floc-forming compounds serve a definite purpose in external treatment for clarification of turbid waters. The gels which these produce are stable in alkaline solution but are redissolved by acids. If the precipitation is effected at higher temperatures, the material which separates may be described as sandy rather than gelatinous. The higher the temperature the more sandy. To find a substance which has the requisite physical and electro-chemical properties for use in boiler-water conditioning, the field of organic materials was explored. A vast amount of data is available relating to the theoretical and practical aspects of these investigations.[8]

The impurities in water consist of dissolved and suspended matter. Carbon dioxide, oxygen, salts, bases, acids and organic matter may be dissolved in the water. Suspended matter generally is in the form of organic matter, insoluble salts or oxides. The mechanism of the action of a suitable colloid may be followed step by step. Any solid material in suspension will be sheathed and protected so that it cannot become a nucleus for crystal growth. In addition, the sheathing action prevents the mass from adhering to the heating surfaces of the boiler because these dispersed particles are highly hydrophilic[9] in character and resist dehydration even when they impinge on the heating surfaces. The

[5] Fowler, "Statistical Mechanics" (1929), p. 328.

[6] J. Alexander, "Colloid Chemistry, Theoretical and Applied," Vol. 1, p. 620.

[7] E. M. Partridge, Power, Vol. 60, p. 56.

[8] F. R. Escorrou, Chimie and Industrie, Vol. 23, p. 273–93 (1930), D. K. French, Industrial and Engineering Chemistry, Vol. 15, p. 12–39 and Vol. 16, p. 206, O. F. Anderson, Industrial and Engineering Chemistry, Vol. 16, p. 206.

[9] E. O. Kramer, "Treatise on Physical Chemistry" (second edition), p. 1692.

sheathing action applies as well to the prevention of crystal growth from those materials which have reached a saturation value in the boiler.

The colloidal tang extracts carry electro-negative charges. They are depolarized by certain ions as calcium, barium, iron and aluminum. This results in precipitation and floc formation. For this reason the peptized bodies take care of the scale forming salts present in the water. Since the electrostatic forces, which prevent the agglomeration of the individual particles have been neutralized, they coalesce to form pinhead gels.

Gels are both adsorptive and absorptive, removing soluble impurities from solution. These flocculate. When a floc gains sufficient weight it tends to settle, and these consolidated aggregates collect in the mud drum to be carried off in the blowdown water.

Pseudo Solutions

When solutions were first discovered possessing those properties which are now termed colloidal characteristics, chemists called them "pseudo-solutions" because a better terminology was lacking. Since that time the cloak of mystery which surrounded the properties of these pseudo-solutions has been gradually lifted. A wealth of data has been recorded and analyzed. A distinct branch of physical science has arisen, devoted to this particular study. The laws which apply to the body of a solution and control homogeneous equilibria cannot be applied to surface phenomena. At interfaces, the controlling phenomena are more complex and do not lead to simple mathematical generalizations. On the other hand, the surface phenomena are no longer mysterious. The physicist has provided himself with tools of research which enable him to study the various factors. Particles have been made visible by means of the dark field. The migration of the charged particles under the influence of an electrical current has been demonstrated. The property of adsorption has been treated quantitatively and the various types of colloidal bodies have been classified. Their size has been determined through sedimentation experiments, and with the ultra-centrifuge and by ultra-filtration. Magnitudes have been found to range from near micronic (diameter = 0.001 mm.) to amicronic (diameter = 0.0000001 mm) dimensions. From these values the enormous surface areas coincident with relatively small volumes may be shown. Because of their specific and selective properties, many colloids have found industrial application.

The factor of economy must be judged on its own merits for any particular installation. The use of storage basins, settling tanks or filters, is a matter of common sense engineering where these are required. The actual introduction of chemicals or water conditioning materials lies in the province of the hydrological engineer or industrial consultant. With boilers operating at high pressures the hazards involved are obvious, and competent advice and service is demanded to insure safety and efficiency. There is no good reason why the operator of a small plant should not benefit by the experience gained under more difficult operating conditions. The physical properties of a suitable colloid material can be utilized to overcome the destructive impurities in feedwater which reach the boiler itself. Since minute quantities of impurities are concentrated in the boiler, it is logical that the boiler water should be subject to treatment to insure against damage. When any appreciable amount of impurity reaches the boiler, the conditioning of the water is essential to safe and economical operation.

The wasting of boiler metal, pipes and fittings by corrosive forces, and the elements which cause embrittlement are subjects worthy of special consideration. Scale removal is a topic which should not be confused with scale prevention. The activity which distilled water exhibits in a boiler system requires separate treatment. Each of these subjects is a chapter in the study of water conditioning.

90 per cent Reduction in Smoke Violations in Three Years

Three years ago New Yorkers had good reason to complain of the dense black smoke that blew across the Hudson River from New Jersey, but now, after three years war on smoke in the Hudson County area, Smoke Abatement Engineer William G. Christy of the Hudson County Smoke Department, reports a reduction of 90 per cent in smoke violations on all classes of fuel burners. This, he estimates, amounts to about 85 per cent actual reduction in smoke density over the 3-year period. To quote from his Annual Report, he says:

"I lay this improvement chiefly to the fact that fuel users are sold on the idea that they save fuel in proportion to the smoke they abate; and have found in practice that it is true. I find it necessary to take court action against only those who have no time to abate smoke."

Out of 10,388 stack readings taken in 1933 of locomotives operating in Hudson County, 330 violations have been noted. Using the standard Ringelmann Chart as a basis for measuring smoke, railroad smoke density averaged 3.45 per cent for the year 1933, a reduction of 86 per cent since the Smoke Department began to function in May, 1931. In 1933, 17,049 observations were taken of industrial plants. Of this number there were only 396 violations; a reduction since May, 1931, of 91 per cent in violations. Out of 2933 observations last year on tug boats and steamers, 54 violations were noted. This amounts to a reduction in violations in this class of 97 per cent since 1931.

New Regulator Company

The General Regulator Corporation, 50 Church Street, New York, manufacturers of regulators and combustion control systems announce the election of the following officers: C. J. King, President; R. A. Wright, Vice President; F. H. Plum, Vice President and Secretary. The above officers were formerly President, Sales Manager, and Vice President respectively of the Smoot Engineering Corporation. J. W. Ackley is Treasurer. Under this management which has had sixteen years' experience in the design, manufacture and operation of regulators and combustion control systems, the General Regulator Corporation is now ready to place on the market a line of regulating equipment featuring a new stabilizing principle.

Derivation of Combustion Formulas

This article is supplemental to the series of articles by this author and Mr. Cruise dealing with the combustion characteristics of fuels and combustion formulas which have appeared in COMBUSTION during the past sixteen months. The present discussion deals particularly with formula for calculating the volume of products of combustion as necessary to the proper design of stacks and breechings and the selection of draft fans.

By P. B. PLACE
Combustion Engineering Company, Inc.

THE volume of the total products of combustion is essential data for the design of stacks and breechings and for the choice of draft fans. By total products of combustion is meant both the dry gases and water vapor. The latter includes all water vapor from the moisture in the fuel, from water vapor in the air used for combustion, from the combustion of hydrogen in the fuel, or from any other sources.

A common formula for calculating the volume of the total products of combustion in cubic feet per pound of fuel is given as

$$\left[\frac{(29.9 \times C_b)}{(CO_2 + CO + CH_4 + 29.9R)} + \frac{(9H_2 + W)}{0.05}\right]\left[\frac{(460 + t)}{492}\right]$$

In this formula C_b is the pounds of carbon burned per pound of fuel, or in most cases the percentage of total carbon in an ultimate analysis of the fuel, expressed as a decimal. H_2 and W are similarly weight fractions of hydrogen and moisture as given in an ultimate analysis of the fuel. CO_2, CO and CH_4 are percentages by volume of these constituents in the dry flue gases expressed as decimals. R is the pounds of soot per cubic foot of gases and t is the temperature of the gases in degrees Fahrenheit.

The values R and CH_4 are seldom determined in the usual flue-gas analysis and are not present in appreciable amounts under normal operating conditions. Leaving these two items out, the formula simplifies somewhat to

$$\left[\frac{(29.9 \times C_b)}{(CO_2 + CO)} + \frac{(9H_2 + W)}{0.05}\right]\left[\frac{(460 + t)}{492}\right]$$

This formula may be divided into three parts for purposes of explanation. The first part $\frac{29.9\ C_b}{CO_2 + CO}$ gives the cubic feet of dry gases per pound of fuel under standard conditions of 32 F and atmospheric pressure.

Per cent by volume is numerically the same as per cent by mol[1] and if volume fractions are multiplied by the proper molecular weights we get weight fractions of the respective constituents. In one mol (molecular weight) of the dry gases there are CO_2 mols of carbon dioxide, CO mols of carbon monoxide, O_2 mols of oxygen, etc. Also each mol of carbon dioxide (CO_2) contains a mol of carbon (C) and a mol of oxygen (O_2). Similarly each mol of carbon monoxide (CO) contains a mol of carbon (C) and half a mol of oxygen (O). Therefore, in one mol of the dry gases there is $[C(O_2) + C(O)]$ mols of carbon and since each mol of carbon represents 12 lb of carbon, the mols of dry gases per pound of carbon is equal to $\frac{1}{12CO_2 + 12CO}$. The weight of carbon burned per pound of fuel is C_b and the mols of dry gases per pound of fuel is equal to $\frac{1 \times C_b}{12CO_2 + 12CO}$.

A mol or molecular weight of any substance in gaseous form under the same conditions of temperature and pressure has a definite volume. This volume, called the molecular volume, is equal to 359 cu ft when the mol is in pound units of weight and the temperature and pressure are standard at 32 F and atmospheric pressure, respectively. Therefore, the volume of dry gases per pound of fuel under standard conditions is equal to $\frac{359 \times C_b}{12(CO_2 + CO)}$ or $\frac{29.9C_b}{CO_2 + CO}$ which is the first part of the given formula.

The carbon balance between fuel and flue gases is represented by $\frac{C_b}{CO_2 + CO}$. The C_b is the total carbon in the fuel that is gasified and which appears in the dry gases. Total carbon in the fuel should be corrected for carbon-in-the-refuse losses. The item R is essentially a solid carbon loss and if appreciable should preferably be involved in the C_b item the same as unburned carbon in the refuse. CH_4 and even CO are usually absent and are of minor importance. Undetermined CH_4 and CO will often be balanced by the presence of SO_2 which is determined as CO_2 in an Orsat analysis of the gases.

Formula Applied to Gaseous Fuels

In the case of gaseous fuels, the analyses of which are generally on a volume basis, an ultimate analysis by weight must first be calculated to determine the value of C_b and H_2. Although C_b is understood to be carbon burned, it would better be designated as carbon gasified. In the case of gaseous fuels containing CO_2, the carbon in this CO_2 is not burned during the combustion of the fuel yet it does appear in the dry gases and must be included in C_b. Gaseous fuels are easily handled on a mol basis and the conversion of volume analyses to ultimate weight analyses is explained later.

The second part of the formula $\frac{9H_2 + W}{0.05}$ represents the volume, in cubic feet per pound of fuel, of the water vapor in the gases under standard conditions of temperature and pressure.

[1] Fuel Performance Calculations, COMBUSTION, October 1932.

The weight of water vapor resulting from the combustion of hydrogen is always 9 times the weight of the hydrogen, as seen by the following equation of the combustion of hydrogen.

$$\begin{aligned} H_2 + O &= H_2O \\ 2 + 16 &= 18 \\ 1 \text{ lb } H_2 &= 9 \text{ lb water vapor} \end{aligned}$$

The density of water vapor under standard conditions is given by the following expression:

$$\frac{\text{Molecular weight of water}}{\text{Molecular volume}} = \frac{18}{359} = 0.05 \text{ lb per cu ft}$$

and dividing the pound of water vapor per pound of fuel by the density gives the volume of water vapor. This volume is added to the volume of dry gases to give the total volume of products of combustion.

In addition to water vapor from hydrogen and from moisture in the fuel, the gases will also contain water vapor from the air used for combustion. This water vapor is in the order of 0.1 to 0.2 lb per pound of fuel, and is calculated from the weight of air used for combustion and the humidity of the air. Since this item is generally larger than the moisture-in-the-fuel item, it should be included in the formula.

Steam jets, ashpit sprays or other equipment in the furnace may constitute a major source of water vapor and some estimate should be made of the amount and included in the calculations. The second part of the given formula in more complete form then becomes

$$\frac{9H_2 + W_1 + W_2 + W_3}{0.05}$$

where W_1, W_2 and W_3 are the weights of water vapor in pounds per pound of fuel from moisture in the fuel, from water vapor in the air supply and from all other sources.

The third part of the formula is the standard temperature correction and should need no explanation. It corrects the volume from standard conditions of 32 F to the desired gas temperature.

The pressure existing in furnaces and boiler flues is so near to standard atmospheric pressure that no correction is usually necessary. As a matter of interest, if such correction is desired, a fourth part would be involved in the formula as follows:

$$\left[\text{Part 1} + \text{Part 2}\right]\left[\text{Part 3}\right]\left[\frac{29.92}{B + \frac{p}{13.6}}\right]$$

where B is the barometer pressure in inches of mercury and p is the inches of water pressure (plus or minus) in the flue. The value 13.6 is the inches of water equivalent to 1 in. of mercury and 29.92 is standard atmospheric pressure in inches of mercury. The latter has no relation to the 29.9 value in part 1 of the formula.

Gaseous fuels are usually on a volume basis and must be converted to a weight basis for application to the foregoing formula. The conversion of volume analyses to weight analyses is easily done by the mol method. A coke oven gas has been chosen for example as it contains most of the constituents found in gas fuels. The molecular weight of the fuel gas is first determined and then, through a molecular analysis of the fuel an ultimate analysis by weight is calculated.

CALCULATION OF MOLECULAR WEIGHT OF FUEL GAS

Constituent	Fuel Analysis Per cent by Volume		Mol Wt of Constituent		Lb per 100 Mols* of Fuel		Mol Wt of Fuel		Per cent by Weight of Constituent
CH_4	30.7	×	16	=	492	÷	11.8	=	41.70
C_2H_6	2.5	×	30	=	75	÷	11.8	=	6.36
CO	5.6	×	28	=	157	÷	11.8	=	13.31
CO_2	2.0	×	44	=	88	÷	11.8	=	7.46
H_2	49.7	×	2	=	99	÷	11.8	=	8.39
O_2	0.7	×	32	=	22	÷	11.8	=	1.86
N_2	8.8	×	28	=	247	÷	11.8	=	20.92
	100.0		Mols of fuel	=	1180 lb				100.00
	1.0		Mol of fuel	=	11.8 lb				

* The factor 100 is introduced here to give per cent values in whole numbers instead of decimals.

The calculated analysis by weight in the above table is not in ultimate form. The ultimate analysis is determined as follows through a molecular analysis of the fuel.

MOLECULAR ANALYSIS OF FUEL GAS

Basis: 100 mols of fuel gas

Constituent	Per cent by Volume	Mols per 100 mols of fuel gas: Carbon C	Hydrogen H_2	Oxygen O_2	Nitrogen N_2
CH_4	30.7	30.7	61.4	...	...
C_2H_6	2.5	5.0	7.5	...	...
CO	5.6	5.6	...	2.8	...
CO_2	2.0	2.0	...	2.0	...
H_2	49.7	..	49.7	...	...
O_2	0.7	..	...	0.7	...
N_2	8.8	..	...	...	8.8
	100.0 Mols	43.3	118.6	5.5	8.8

CALCULATION OF ULTIMATE ANALYSIS BY WEIGHT

Constituent	Mols per 100 Mols of Fuel		Mol Wt of Constituent		Lb per 100 Mols* Fuel		Mol Wt of Fuel		Ultimate Analysis Per cent
Carbon C	43.3	×	12	=	520.0	÷	11.8	=	44.1
Hydrogen H_2	118.6	×	2	=	237.2	÷	11.8	=	20.1
Oxygen O_2	5.5	×	32	=	176.0	÷	11.8	=	14.9
Nitrogen N_2	8.8	×	28	=	246.3	÷	11.8	=	20.9
	100 mols fuel			=	1179.5 lb				100.0
	1 mol fuel			=	11.8 lb				

From this ultimate analysis we obtain C_b equal to 0.441 and H_2 equal to 0.201 and as pointed out before, C_b represents not only the carbon in CH_4, C_2H_6 and CO that is burned but also the carbon in the CO_2 that is not burned in the furnace but which must be accounted for in the carbon balance. In the case of gas fuels, W_1 is the water vapor in a pound of the fuel gas and unless definitely known, W_1 may be taken equal to the weight of water vapor in saturated air at fuel gas temperature, as given in any psychrometric table or chart.

Roots-Connersville Blower Corporation—At the annual meeting of the stockholders of The Connersville Blower Co., Inc. held on January 23, 1934, action was taken to change the name of the company to Roots-Connersville Blower Corporation, thus indicating to the public the units making up the company. The management of the company will continue as heretofore, without any change in personnel. One of the units now comprising Roots-Connersville Blower Corporation dates back to 1854, and all have engaged in building the same line of equipment for many years, including rotary positive blowers, gas pumps, gas meters, liquid and vacuum pumps, etc. Within recent years, a complete line of centrifugal pumps and blowers has been introduced.

Water Conditions and Related Problems of Marine Boiler Operation*

By A. C. PURDY
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The author discusses control based on the phosphate radical to prevent scale formation under the high rates of heat transfer obtained in marine practice, and favors the use of sodium metaphosphate with proper hydrogen ion (pH) adjustment. He stresses the necessity of keeping the boiler water free from organic matter to prevent carry-over and believes raw make-up water preferable to distilled water. Corrosion, cracking and embrittlement prevention are also discussed.

MARINE boiler operation has followed the trend of power stations ashore as to higher pressures, larger units and higher ratings. With these changes has come the necessity for more careful consideration of water conditions. The function of water conditioning in assuring continuous steam production involves, (1) the prevention of scale formation, (2) control of corrosion and (3) dry steam production.

Boiler Scale and Its Prevention

Owing to the high rate of heat transfer, which may reach 125,000 Btu per sq ft per hr in the fire-row tubes of present-day merchant-marine, oil-fired boilers operating at 350 to 400 lb pressure, the permissible thickness of scale formation before tube failure occurs is very slight. Assuming a heat conductivity coefficient of 1.3 Btu per sq ft per hr per ft per deg F, as an average for a dense calcium sulphate scale, tube failure might be expected if a scale of this character reached a thickness of 0.058 in. In a recent case tube failures did occur in a marine boiler operating at 350 lb with an average scale thickness, near the point of failure, of 0.044 in.

Owing to limitations in the use of soda ash at higher pressures, the equilibria control based on the phosphate radical has found more general application. As a source of the phosphate radical there are available the orthophosphates—trisodium, disodium and monosodium phosphates, and the sodium metaphosphate and pyrophosphate. Phosphoric acid has been used but is difficult to handle.

Prior to the researches of Hall, the control of treatment with phosphate was based on the condition of the boiler when opened, or at times upon the alkalinity or hardness of the boiler water. His work on chemical equilibria proved that definite control of conditioning must be based on control of the phosphate radical.

Disodium can be used in place of trisodium phosphate, where less alkalinity is desired. Monosodium may also be used for alkalinity reduction, but it is acid and must be injected directly into the boilers and used with great care. In our own work we prefer to use sodium metaphosphate with proper hydrogen ion (pH) adjustment in order that the control of excess phosphate can be effected irrespective of the alkalinity. To assure scale prevention, inhibit corrosion and embrittlement, and assure proper steam quality, it is necessary to maintain in the boiler water sufficient excess phosphate to meet the required phosphate/sulphate ratios, while at the same time holding the alkalinity above a minimum necessary to prevent corrosion and below a maximum above which there is a risk of wet steaming and danger of embrittlement. These limits depend upon the installation but 50 to 250 ppm or 3 to 15 grains per gal (as sodium hydrate) might be considered as the extreme limits.

Thus there are two independent variables which must be controlled—excess phosphate and alkalinity. Except where the feedwater is of constant composition, permitting the choice of a sodium phosphate which gives just the right amount of both phosphate and alkalinity, it is necessary to control these two variables by the controlled addition of two chemicals—one a phosphate chemical giving insufficient alkalinity, the other an alkali chemical capable of building up and maintaining the desired alkalinity. We have found sodium metaphosphate and caustic soda the ideal combination to accomplish this balance. The metaphosphate, can be added at the hotwell or other convenient place in the feed system and, being neutral, it passes through the feed lines without setting up corrosion therein.

Feed Line and Heater Scale

The use of orthophosphates, with proper control of alkalinity and excess phosphate, is often accompanied by trouble with pre-boiler deposits. These deposits, high in calcium phosphate, tend to form particularly in heaters, but also may be found in feed lines, feed pumps, valves and economizers. Some relief may be obtained by the use of colloidal organic materials, tending to stabilize the super-saturated solution, but these organic materials are considered by the author as undesirable in the boiler.

For the protection of superheaters and turbines,

* Excerpts from paper before the Society of Naval Architects and Marine Engineers, New York, November 16 and 17, 1933.

carry-over must be reduced to a minimum. Research and experience indicate that dissolved and suspended solids can be safely carried in high concentration in the boiler water without seriously affecting steaming if the boiler water is kept free from organic matter, particularly saponifiable or soap-forming organic matter, and if the alkalinity of the water is held at or near the minimum found necessary for corrosion control. The sectional-header, cross-drum marine boiler, operating at prevailing pressures and ratings will stand quite high concentrations in the feedwater, if these conditions are complied with.

The most serious case of carry-over that we have investigated, however, involved the destructive corrosion of turbine blades (54 per cent copper, 44 per cent zinc, 1 per cent nickel), resulting apparently from corrosive sulphur oxides present in the steam. At the temperature prevailing in superheaters, organic matter will reduce sulphates to sulphides and these in the presence of water vapor at red heat will produce sulphur dioxide and hydrogen. The sulphur dioxide will produce serious corrosion in the turbine as soon as a stage is reached where sufficient moisture is present to permit the reaction to proceed.

Corrosion

Corrosion protection should begin with a careful study of the design and the layout of the water cycle, proper consideration being given to the mechanical means available for removal of oxygen from the feedwater and to its protection from subsequent contact with air. In view of the very high percentage of condensate, which in the modern marine installation is satisfactorily free from oxygen, owing to the general use of efficient air ejectors, it should be comparatively simple to provide a practically zero oxygen feedwater supply to marine boilers.

Chemical methods of inhibiting corrosion fall into two classes—the formation of protective films and the fixation of dissolved oxygen. The maintenance of alkalinity in the boiler is essentially a film protection, since it gives rise to a protective film of ferrous hydroxide polarizing the iron surface. Experience has shown that feedwater should have an alkalinity equivalent to a hydrogen ion concentration (pH) of 8 to 10 to protect feed lines, heaters and economizers. The boiler itself should never be below 10 and is best maintained slightly higher, approximately 11 to 11.5 in the majority of cases.

Chromates, also, form protective films and we have found them very successful for the protection of laid-up boilers. However, they have not been used widely in steaming boilers because of certain generally recognized disadvantages.

Tannins Long Used

As oxygen-fixing chemicals the various tannin materials have long been used and are still a familiar ingredient of boiler compounds and treatments in the marine field. It is questionable if these materials have any real value for this purpose, even when employed at low temperatures.

Two inorganic salts have been used with success as oxygen fixers in high-pressure installations. They are ferrous hydroxide and sodium sulphite. Owing to the difficulties attending the preparation and use of the former, it is doubtful if it will find application in the marine field. However, sodium sulphite does offer excellent possibilities, particularly if economizers come into more general use, requiring a greater degree of oxygen removal than can usually be assured by mechanical means.

Cracking, Corrosion Fatigue or Embrittlement

In the light of present knowledge, it is proper to consider boiler metal cracking as the joint result of corrosion and stress. The peculiar intercrystalline type of corrsion associated with corrosion fatigue or embrittlement failures in boilers results from the attack of high caustic alkalinity. The recognized method of protection is incorporated in the A.S.M.E. Code for the Care of Boilers. This portion of the Code prescribes certain ratios between the alkalinity and the sulphate present in the boiler water. The purpose of maintaining sulphate in the boiler water is to assure its presence as a protective layer on the metal.

Distilled vs Raw Makeup

Practically all discussions of feedwater conditions, with reference to marine boilers, tend to emphasize the necessity of reducing dissolved and suspended solids to a minimum and lay stress on the use of distilled makeup water for boilers operating at 300 to 450 lb. Actual operating experience indicates that, given a reasonably good bunker water, it is unnecessary and uneconomic to resort to evaporator operation, in view of the very high percentage of condensate return and the predominating influence of condenser leakage on the character of the feedwater, which influence is exerted whether or not evaporators are used.

From the personnel standpoint it is more satisfactory to have the operators used to controlling the water conditions resulting from the use of raw water with some scale-forming salts continually entering with the feedwater, since this constant vigilance makes it much easier to assure satisfactory handling of condenser leakage when it does occur.

Certain other advantages accompany the use of raw makeup. The concentration in the boiler of sulphates nomal to the raw water reduces and often eliminates entirely the addition of sulphates, which must otherwise be purchased and added to the feedwater to bring the boiler water alkalinity to sulphate ratio in conformance with the A.S.M.E. Code requirements. Furthermore, the phosphate sludges which develop in phosphate treatment serve a very useful function in adsorbing traces of oil.

These sludges will adsorb oil up to 15 to 20 per cent of their dry weight, without changing their character sufficiently to interfere with their free circulation in the boiler water. The quantity of sludge formed is, of course, proportional to the scale-forming salts entering the boiler with the feedwater. In the absence of condenser leakage, very little sludge is precipitated with evaporated make-up and, therefore, very little oil can be handled in the boiler water. In the interest of obtaining the maximum economy without sacrifice of safety or continuity of operation, the advisability of using raw make-up should receive careful consideration, for a number of ships are operating in this way at pressures of 400 pounds and above with entire satisfaction.

Warranty of Plans and Specifications for Steam Line

By LESLIE CHILDS, Attorney
Indianapolis, Indiana

According to the decision of the court, where the contract contains both general and special provisions, relating to the same thing, the special will prevail over the general provisions. In this particular case the contractor was held to have complied with the specifications as drawn by the plaintiff's engineers and was not held liable for the performance of the steam line as laid down in the general provisions of the contract.

GENERALLY speaking, a contract for the construction of a steam line, according to plans and specifications furnished by the owner, will not obligate the contractor in respect to warranty of performance. And, when the contractor has performed in accordance with the plans and specifications furnished, he will be deemed to have discharged his obligations under the contract.

Further, mere general provisions in such a contract—that the completed work shall be suitable for a named performance—will not change the rule, where special provisions relating to the same subject are present and indicate otherwise. For here, the general rule will usually be held subordinate to the special and if relied upon by an owner may prove highly deceptive.

This is a point that may well be kept in mind by owners and operators of steam plants when construction contracts are being entered into. As an illustration of the application of the foregoing, State vs. Commercial Casualty Insurance Company, Supreme Court of Nebraska, 248 N. W. 807, may be examined with profit.

Contract for Construction of Steam Line Entered Into

Here the plaintiff let a contract for the construction of a steam line to the defendant. The contract provided that the work should be performed in accordance with the plans and specifications furnished by the plaintiff, and under the direction and supervision of the latter's engineers. The principal part of the line, it appears, was to be installed in a tunnel. The contract provided in detail the size of pipe to be used at different points; the location of expansion joints and manholes; named the material to be used in the joints, and stipulated how the main pipe should be anchored in the tunnel. The contract also contained a general provision to the effect that:

"The pipe line when finished should be suitable for carrying steam at a pressure of 250 lb per sq in. and superheat of 150 deg."

Defendant entered upon the work, and completed same under the supervision of plaintiff's engineers. He was paid from time to time on the monthly estimates. Upon completion the plaintiff's engineers made a final estimate, approved the work, and the defendant was paid in full upon the authority of the engineer's certificate.

Following this, it developed that the pipe line was insufficient for the purpose intended. The plaintiff thereupon brought action upon defendant's bond for breach of contract. Here the plaintiff, among other things, charged that the expansion joints were not of the proper pattern; that the anchors were insufficient; that insufficient expansion was provided; that the expansion joints should either have been placed closer together or a greater expansion provided for; and that because of these deficiencies in construction the line was not suitable and safe for carrying steam at 250 lb and 150 deg superheat, as called for by the *general* provision of the contract noted heretofore.

Defendant replied by contending that he had complied with the plans and specifications in detail, and that he should not, therefore, be held liable for any deficiency in performance of the completed work. Plaintiff countered on the theory that the general provision of the contract, which provided that the line should be suitable and safe for carrying steam at 250 lb pressure and 150 deg superheat, constituted a warranty on the part of the defendant of this performance.

Upon the trial, the court found that the defendant had followed the plans and specifications furnished in all respects, and had discharged his full duty under the contract. The court, therefore, declined to construe the general provision of the contract as a warranty by the defendant and gave judgment for the latter. The plaintiff appealed and the higher court in affirming the judgment, in part, said:

Language of the Court

"Much stress is laid upon the provision of the contract that the pipe line should be suitable for carrying steam at 250 lb pressure to the square inch and superheat of 150 deg. It is contended that this is a warranty that the pipe line, when completed, will be suitable for such purpose.

"It is a rule that, where there are general and special provisions in a contract, relating to the same thing, that the special will control over the general provisions,

and, if the contract is fulfilled according to the special provisions, the contractor has fully complied with the terms of his contract.

"Whether the pipe line, as designed by plaintiff's engineers, and the specific material required and manner of construction were sufficient were questions on which the contractor was not required to pass judgment. His duty was to perform and fulfill the contract according to the specific terms and directions therein. * * *

"Where plans and specifications for an improvement are prepared by engineers of the owner, who are to inspect and supervise the construction and see to it that materials are furnished and work performed in accordance with the specifications, ordinarily the contractor is not liable for the sufficiency of the specifications, but only for the skill with which he performs the work and the soundness of the materials used by him. * * * Judgment affirmed."

Conclusion

At first blush, it may seem that dispute and litigation would rarely arise over the point involved in the case reviewed. On the contrary, the books contain case after case of this kind; ample proof that the subject is a prolific source of litigation in the construction field. And the reports in a surprising number of these cases clearly indicate their inception, namely, a failure to adequately define the warranty obligations in the contracts involved. In view of which, the exercise of care here would seem well worthwhile as insurance against subsequent dispute on this much litigated subject.

What Chicago is Doing to Fight Smoke

Civil Works Administration funds have made it possible for the City of Chicago to employ a large corps of engineers for the purpose of attacking the smoke nuisance, this force to supplement the activities of the Department of Smoke Inspection and Abatement under the jurisdiction of Deputy Smoke Inspector, Frank A. Chambers. The main objectives of this campaign are:

First, to detect smoke violations and by scientific analysis determine the percentage of air-pollution chargeable to the various types of furnaces.

Secondly, to advise with owners whose plants violate the City Smoke Abatement Ordinance as to the corrective methods to be instituted for the purpose of eliminating the offense.

Thirdly, to make a survey of all heating, power and industrial plants for the purpose of suggesting to owners improvements advisable to be made in the boiler rooms for the purpose of insuring against the emission of any smoke and for more economical operation of the plant so that violations will not occur in the future. Thus permanent good will be accomplished by this Civil Works Administration project.

For this initial purpose one hundred and fifty engineers out of a total quota of five hundred are now in the field making smoke observations and instructing operators.

REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

A.S.T.M. Book of Standards 1933 Edition

THE American Society for Testing Materials has recently issued its Book of A.S.T.M. Standards, a triennial publication containing all of the standard specifications, methods of test, recommended practices and definitions formally adopted by the Society.

The 1933 issue of this publication is composed of two parts: Part I contains all A.S.T.M. standards covering metallic materials; Part II, all standards relating to non-metallic materials. In both parts of the book, the specifications for a particular class of material are given first, followed directly by the test methods, definitions, etc. A complete subject index is included in which each standard is indexed under the principal subject covered, key words being given in alphabetical sequence. This index, together with two tables of contents, one listing standards by the materials covered, the other in order of numeric sequence of the designations, greatly facilitates the use of the book.

Part I: Of the 185 standards in Part I, 104 cover the ferrous metals, steel, wrought iron, pig iron and castings, and ferro-alloys, while 70 relate to non-ferrous metals, including aluminum and magnesium alloys, copper and copper alloys, lead, nickel, zinc, bearing metals, solder metal, deoxidizers, electrical-heating and electrical-resistance alloys. Eleven of the standards involve metallography and general testing methods.

During 1933 many new standards were adopted relating to widely used materials. In Part I the following materials are covered by new specifications: soft steel track spikes, structural rivet steel, marine boiler steel plates, structural steel for ships, heat-treated carbon-steel helical springs, lap-welded and seamless steel and lap-welded iron boiler tubes, austenitic manganese-steel castings, open-hearth iron plates of flange quality, steel plates of flange and firebox qualities for forge welding, fire-refined copper other than lake, silver solders, electrical-resistance alloys, seamless copper tubing and copper water tube.

Revisions in some forty of the existing standards covering metallic products were adopted during 1933. Materials covered by these standards include the following: steel tie plates, structural silicon steel, boiler and firebox steel for locomotives and for stationary service, concrete reinforcement bars, wrought-iron bars, zinc (hot-galvanized) coatings on structural steel shapes, zinc-coated articles, slab zinc spelter, brass pipe, sheet high brass.

Part II: Included in the 285 standards contained in Part II—Non-Metallic Materials—are specifications and test methods covering the following general classes of materials: cement, lime, gypsum, masonry building units, refractories and fire brick, pipe and drain tile, concrete and concrete aggregates, coal and coke, timber and timber preservations, naval stores, paints, varnishes, lacquers and paint materials, petroleum products and lubricants, road materials, waterproofing and roofing materials, rubber products, textile materials, slate, electrical insulating materials, thermometers.

The number of new standards adopted in 1933 covering various non-metallic materials totals 37. The following materials and tests are covered by these new methods: fire tests of construction materials, gypsum and gypsum products, raw tung oil, boiled linseed oil, linseed oil putty for glazing, shellac, crankcase oils, petroleum and its products, insulating materials, knit goods, asbestos electrical tape, chafer tire fabrics, enameling duck for tire industry.

Revisions in several important standards were adopted during 1933. Those materials covered by standards in which important changes were made include: refractory materials, sands for concrete, white pigments, petroleum products, structural timber, joists, planks, etc., creosote oil, molded electrical insulation.

Both parts of this book aggregate 2300 pages, size 6×9. Price: either part $7.50; both parts $14.00.

Steam, Air and Gas Power

(Second Edition)

By William H. Severns and Howard E. Degler

THE second edition of this elementary text on Heat Engineering has been brought completely up-to-date. New descriptions and new illustrations of recent power plant equipment take the place of the material which was considered obsolete and of least importance by the authors.

The scientific and engineering symbols and abbreviations used in this book are in general accordance, except for the use of a period after each abbreviation, with the American Tentative Standards approved by the American Standards Association.

The contents of the book, as indicated by the chapter headings, are as follows: Principles of Thermodynamics; Heat Power Plants; Steam and Steam Calorimetry; Fuels for Steam Gemeration; Combustion and Flue-Gas Analysis; Steam Generators or Boilers; Steam Generator Auxiliaries; Feedwater Treatment and Feedwater Heaters; Draft Apparatus, Chimneys and Fans; The Steam Engine; Valves, Valve Gears and Governors; Steam Engine Economy; Multivalve and Multiexpansion Engines; Steam Turbines; Steam Condensing Equipment; Pumps; Compressed Air; Internal Combustion Engines.

The current A.S.M.E. steam tables, compiled by Professor Joseph H. Keenan, are included in slightly abridged form in the chapter "Steam and Steam Calorimetry." A removable copy of the Mollier diagram is inserted in the inside back cover.

The book contains 480 pages, including a comprehensive index, size 6×9. Price $4.00.

ENGINEERING BOOKS

Any Book in Print May be Ordered Through Our Book Department—Order Form on Opposite Page

1—Handbook of Oil Burning

By Harry F. Tapp

629 pages Price $3.00

Contains information of practical value to the engineer or contractor whose work requires a knowledge of oil burning, heating or power equipment. Covers comprehensively the industrial application of oil as fuel, with drawings, illustrations and tables of this style of installation. Also discusses the various types of oil burner and principles of construction, oil burner controls and motors and fuel tanks and storage. Contains also a wealth of general information such as the chemistry of combustion and flame, fundamentals of heat and heat transfer, the determination of heating capacity requirements and comparative fuel costs.

2—The Engineer's Manual of English

By W. O. Sypherd and Sharon Brown

526 pages Price $2.00

The Engineer's Manual of English is a practical guide for all technical writing which the engineering student may need to do while in college and later on in connection with his professional duties.

The book is divided into two parts: "Engineering Writing" and "Specimens of Engineering Writing." The first part deals with the application of the principles of formal rhetoric to the actual problems of the engineer-writer. The second part comprises a complete collection of specimens of engineering writing.

3—The Calculation of Heat Transmission

By Margaret Fishenden and Owen A. Saunders

280 pages $5^3/_4 \times 9^3/_4$ Price $3.00

The Calculation of Heat Transmission by Dr. Margaret Fishenden and Owen A. Saunders of England was prepared under the auspices of the Fuel Research Board of the Department of Scientific and Industrial Research. In it an attempt is made to bring together in accessible form the various experimental results described in the mass of scattered literature now available on the subject. Complicated theory and specialized technical applications have been avoided, but, wherever feasible, results have been interpreted and compared in the light of fundamental principles of conduction, convection and radiation.

The main chapter headings are as follows: Radiation; Calculation of Radiation Heat Transfer; Emission and Absorption of Radiation by Gases and Flames; Conduction; Calculation of Conduction Heat Transfer; Convection; Natural Convection in Gases; Forced Convection in Gases; Convection in Liquids; Heat Transfer Calculations.

4—A.S.M.E. Power Boiler Code (1933 Edition)

314 pages $5^1/_2 \times 8$ Price $2.50

The new edition of the *A.S.M.E. Power Boiler Code* incorporates the revisions, extensions and additions to rules and specifications that have been made during the past three years. It contains Sections I, II and VI of the *A.S.M.E. Boiler Construction Code*, covering, respectively, Power Boilers, Material Specifications, and Rules for Inspection.

5—Heat Transmission

By William H. McAdams

383 pages $5^3/_4 \times 9$ Price $5.00

This book, which is sponsored by the Committee on Heat Transmission of the National Research Council, is designed to serve both as a text for students and as a reference for practicing engineers. Fundamentals rather than details of individual problems and special cases are presented.

The appendix contains tables and charts of thermal conductivities, specific heats, latent heats of vaporization, viscosities, steam tables and dimensions of steel pipe, and the bibliography contains over 500 carefully-selected references.

6—Handbook of Chemistry and Physics (Eighteenth Edition)

1818 pages $4^1/_2 \times 6^3/_4$ Price $6.00

For twenty years the *Handbook of Chemistry and Physics* has been giving a unique service to those in need of accurate tables, formulas and scientific data in a single convenient volume.

The Eighteenth Edition of this handbook represents a 20-year accumulation of necessary data for the busy scientist and engineer that is not only acceptable but highly essential in the commercial, educational and research laboratory.

7—World Economic Survey (1932–33)

345 pages $6^1/_4 \times 9^1/_2$ Price: cloth bound $2.00, paper bound $1.50

The *World Economic Survey 1932–33* is the second volume of an annual series issued by the League of Nations. The information it contains was collected from all over the world by the Economic Intelligence Service of the League, and it therefore provides an authoritative survey of what perhaps was the most critical year in world economic history.

8—Mechanical Engineers' Handbook

By R. T. Kent

2247 pages 10th Ed Price $6.00

Designer, power-plant engineer, shop-superintendent, heating and ventilating engineer, hydraulic engineer, building constructor, foundryman, automotive engineer, will find this handbook to be a complete reference book covering their field and many others. *Kent* is more than a book, it is a complete library of engineering practice.

9—Draft and Capacity of Chimneys

By J. G. Mingle

339 pages Illustrated Price $3.50

The subject matter of this book has been developed primarily from a theoretical standpoint and then amplified by experimental data gleaned from actual practice.

The author observes that draft, even to the expert, frequently contains an element of mystery, and that there is often a great deal of confusion and misconception on the subject. A careful study of this book will give a thorough and practical knowledge of this important subject. The book is profusely illustrated with graphs and charts. Many valuable tables are included and the index has been prepared for ready reference.

10—American Society of Heating and Ventilating Engineers Guide, 1933 (11th Edition)

592 pages 6 x 9 Price $5.00

The 11th annual edition of this standard reference volume on heating, ventilating and air conditioning has been extensively enlarged and revised to include the latest results of research and modern engineering practice. The Guide 1933 embodies in its 45 chapters not only data developed at the A.S.H.V.E. Research Laboratory and cooperating institutions, but also the most practical and useful ideas of outstanding engineers in the profession.

The 592 pages of text matter in The Guide are supplemented by the valuable Catalog Data Section of Modern Equipment, in which detailed descriptions, sizes, capacities and dimensions of manufacturers' products are given.

11—Steam Power Plant Engineering

By G. F. Gebhardt

1036 pages Price $6.00

One of the truly standard reference books on mechanical engineering. It is a necessary part of the equipment of every one who has to do with steam-power plant engineering.

12—Steam Tables and Mollier Diagram

By Joseph H. Keenan

Price $2.00

These new Steam Tables, extending to a pressure of 3500 lb per sq in. and a temperature of 1000 deg fahr, were developed from the latest experimental data secured by investigators in laboratories of Europe and those of the United States. The Symbols used in this work are taken from the latest test prepared by the A. S. A. Sub-Committee for Heat and Thermodynamics. A large copy of the new Mollier Diagram (23" x 34") is also included.

13—Problems in Human Engineering

By F. Alexander Magoun

585 pages Price $2.60

Here is a real case book in Human Engineering, built around fifty typical difficulties and emergencies that business men have actually had to face. The questions are those that confront men in all ranges of business success, involving relations with superiors, equals, competitors, inferiors, customers, labor and the opposite sex. Almost every personality trait that can help or hinder a man at work is brought into the limelight of discussion.

Following the brief statement of the problem the reader finds a group of the actual answers that students in the Humanics class at the Massachusetts Institute of Technology, which is being conducted by Professor Magoun, worked out and handed in. Good and bad, pro and con, they have been selected to preserve the controversial nature which makes this problem book so stimulating.

14—Finding and Stopping Waste in Modern Boiler Rooms

808 pages Price $3.00

This well-known Cochrane reference book has been revised and enlarged. New matter has been introduced in the section on Fuels, Combustion and Heat Absorption, and considerable material has been added on the subjects of steam and water measurements, water treatment and testing. As a handbook on these subjects, this volume is eminently practical and useful. Every steam plant engineer should have a copy.

15—Bailey's Handbook of Universal Questions and Answers (Sixth Edition)

264 pages $4^3/_4 \times 6^1/_2$ Price $2.00

The questions and answers contained in this Handbook are those that have been universally asked by examining boards and were compiled from over four hundred examination papers, including tests for firemen, engineers and boiler inspectors. It gives information on the subjects of boilers, pumps, fuel consumption, valves, heating systems, engines, etc., and will be of assistance not only to those studying for any grade of license in this country or in Canada but also to the practical engineer and fireman.

The author, A. R. Bailey, is intimately acquainted with the needs of practical engineers and firemen and of candidates for licenses, having served as engineer and boiler inspector in the states of Massachusetts, Ohio, Pennsylvania and Michigan, and as safety engineer for the Lincoln Motor Company, Detroit. The sixth edition of this book, recently published, has been brought thoroughly up to date.

16—Industrial Piping—A Case Book of Proven Practices and Methods

286 pages $5^1/_2 \times 8^1/_2$ Price $3.50

The practical considerations required in planning a new or remodeled piping system call for wide experience and seasoned judgment as well as engineering skill. *Industrial Piping* is a case book describing actual conditions and remedies, written by nineteen engineers whose work in the field of industrial piping has been outstanding. Among the subjects discussed in this book are the following: calculating economical pipe sizes; calculating heat losses; special products available for special jobs; basic consideration in designing hangers; figuring comparative operating and upkeep costs of old steam piping system versus proposed modernized system; formula for figuring friction of steam through pipes; method of balancing the practical and the theoretically perfect calculations for pipe sizes; bending formulas for five types of bends; figuring thickness of insulation material to be applied to flat surface; figuring thickness of two insulation materials to be applied to a flat surface; figuring thickness of insulation to be applied to piping; figuring loss of head of viscous materials through pipe; choosing piping system for oils; installing high and low pressure traps on the same job; arranging piping for easy cleaning.

17—Modern Methods in Quantitative Chemical Analysis

By A. D. Mitchell and A. M. Ward

178 pages $5 \times 7^1/_2$ Price $1.75

The authors offer in this book a critical selection of methods from the bewildering mass of literature available on the subject of analytical chemistry. It is intended that this book should function as a supplement to more standard works by including those methods which have been introduced or perfected within the last decade or so, but electrometric and other physical methods are not included since the description of the technique involved, e. g., in the use of azeotropic mixtures, is precluded by consideration of space.

18—Exhaust Steam Engineering

By C. S. Darling

431 pages Price $7.50

This book is exceptionally rich in material of practical value. Explanations of engineering or scientific principles are brief and clear. The book is of special value as a handbook for the solution of steam plant problems. The subject matter will be as useful in the renovation of old plants as in the design of new ones.

19–Power Plant Management

By Walter N. Polakov

171 pages Price $2.00

This book offers information of considerable value to those concerned with the management or supervision of power plants, and will help to solve many problems.

20—Elements of Engineering Thermodynamics (Fifth Edition)

By J. A. Moyer, J. P. Calderwood and A. A. Potter

192 pages 6 x 9 Price $2.50

In the preparation of the material for the fifth edition of this book, the authors have kept before them their original objective, namely, to stress the fundamental principles of engineering thermodynamics as a foundation for the more advanced and practical applications of the theory.

The subject matter covered, as indicated by the chapter headings, is as follows: Thermodynamic Principles and Definitions; Properties of Perfect Gases; Thermodynamic Processes for Gases; Cycles of Heat Engines Using Gas; Properties of Vapors; Entropy; Thermodynamic Processes of Vapors; Vapor Cycles; Flow of Fluids; Applications of Thermodynamics to Compressed Air and Refrigerating Machinery.

21—Combustion in the Power Plant (A Coal Burner's Manual)

By T. A. Marsh

255 pages Price $2.00

The author's discussion of coals and combustion is simple and understandable. His consideration of equipment—stokers, boilers, furnaces, fans and auxiliaries—is thoroughly practical. He tells how to select a stoker for the best available coal; how to design furnaces and arches; how to analyze draft problems and design chimneys, gas flues and boiler passes; how to purchase coal and calculate steam costs. He gives to every phase of his subject a practical interpretation that makes this book of exceptional value to men actually identified with steam plant design and operation.

22—A.S.T.M. Refractories Manual

93 pages 6 x 9 Price 50 cents

This publication, issued by the American Society for Testing Materials, brings together in convenient form the several A.S.T.M. standard specifications, method of testing and definitions pertaining to refractories. It also includes the latest revision of the Manual for Interpretation of Refractory Test Data.

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NEW EQUIPMENT

of interest to steam plant engineers

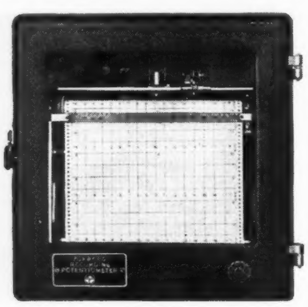
Pyrometer with Novel Features

A new type of balancing mechanism is a feature of the new recording potentiometer pyrometer manufactured by the Foxboro Company of Foxboro, Mass. This balancing device is so designed that it produces a large movement of the pen or print wheel for a small galvanometer deflection and moves the printing mechanism from one end of the scale to the other in a minimum of time, without requiring an extremely fast cycle or rapid motion of the mechanism.

The balancing mechanism consists essentially of a V-shaped drive cam and a friction roller. The sensing fingers, which detect galvanometer deflection, position the friction roller according to the position of the galvanometer pointer. The V-shaped drive cam then engages and rotates the roller, which in turn transmits its straight-line motion to the slide-wire contact, moving it a corresponding distance. The pen or print wheel, being mounted integrally with the slide-wire contact, moves with it, thus making the record coincide accurately with the measurement.

The Recorder is housed in a new fume-tight and dust-proof case that is so designed that it may be either flush or surface mounted. The case aluminum door with large glass window makes the chart and interior of the instrument highly visible.

The entire mechanism can be swung forward out of the case, making every part accessible for inspection. With the instrument in this position, one is able to inspect closely the drive motor of the instrument that is mounted in rubber bushings which silence the motor and prevent

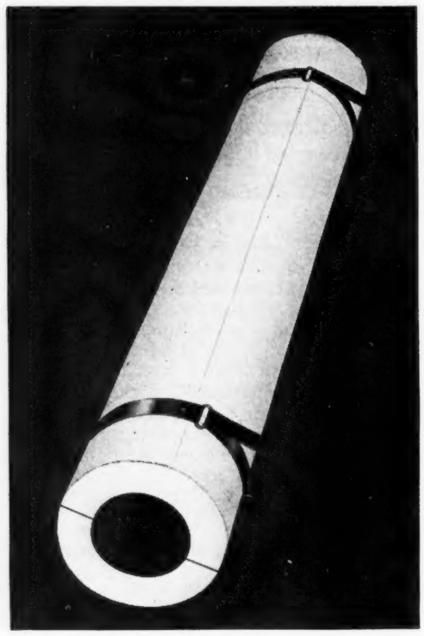


transmission of vibration to the instrument. This synchronous motor is completely enclosed, runs in ball bearings, has a centrifugal starting switch and has no brushes.

New Pipe and Block Insulation

Refractory & Engineering Corporation, New York City, has developed a new type of molded pipe insulation and flat insulating block. The composition of this material is different from the usual commercial molded insulations in that it is designed for use with all steam temperatures, both high or low. A lighter covering of single thickness of the new insulation is said to give an efficiency equal to the usual combination of high- and low-temperature insulations required at moderately high steam line temperatures. Furthermore, it is pointed out that with only a single layer of covering to install, the saving in material (the outer inch or so) is considerable and the labor cost during installation is appreciable.

Another feature of the material is its resistance to moisture and water. After



submergence it simply dries out to its original state and regains its efficiency as it dries. It is furnished in standard molded-type shapes and sizes. Blocks are shipped in cases; pipe insulation in cases, complete with canvas and brass lacquered bands.

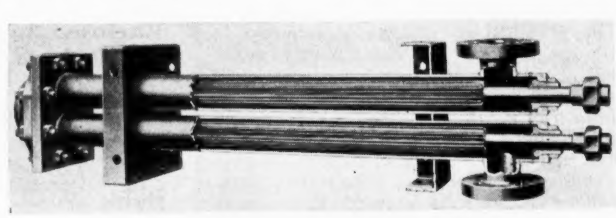
Fuel Oil Heater

A new type of fuel-oil heater recently placed on the market by The Griscom-Russell Company, New York City, has several unique features which provide an exceptionally flexible and compact installation. This is the Twin G-Fin Section, consisting of two parallel steel pipes, each serving as a shell for a single patented G-Fin pipe with a return bend at one end and all inlet and outlet connections at the other end. The G-Fin pipe is made in the form of a U-bend, each leg of which is contained in one of the two parallel pipe shells. These units, being standard and interchangeable, can be arranged in series or parallel as required by the duty, and additional sections can be connected at any time to an existing installation.

This design eliminates the necessity of providing complete spare heating capacity except in installations consisting of only a single unit. Also, individual units can be cut in and out of service at fractional loads to better maintain constant oil temperature.

Besides this feature of flexibility to meet varying service requirements, the G-Fin pipes have an exterior surface more than eight times the area of the interior cylindrical surface. Because of this finned heating surface, the transfer of heat from the steam, which is contained inside of the G-Fin pipe, to the oil flowing along the finned surface will be several times greater than with a bare pipe of equal strength.

Other advantages claimed for this design are the absence of internal joints which might permit leakage between steam and oil and the elimination of strains from changes in temperature because of the free expansion of both the shells and G-Fin pipe.



Helico-Centrifugal Principles Applied to Separator

A separator built on the simple helico-centrifugal principle is being manufactured by The Swartwout Company of Cleveland. The helix or "cork screw" device is located near the inlet of the separator. This gives the entering steam, air or other vapor, a whirling motion. Any liquid or solid matter that is entrained is thrown by centrifugal force to the outside of the separator, where it collects, runs down and is drawn off. No baffle plates and other devices which have a tendency to reduce the pressure are employed. Therefore a high degree of separation is attained with practically no pressure drop.

Portable Combustion Set

An inexpensive, light-weight portable combustion test set has recently been brought out by The Hays Corporation of Michigan City, Indiana. The set comprises a Hays CO_2 analyzer and a dry-type pointer gage, housed in a sturdy stamped spot-welded steel case. A small

fountain-pen type flue-gas thermometer, having a range of 200 to 800 F can also be supplied if desired.

The entire set weighs only 9 lb, and its dimensions are $7^7/_8$ x 5 x 15 in. There are convenient reels and clamps for the rubber tubing and accessories and the carrying handle swings out of the way when unsnapped.

The National Bureau of Engineering Registration

Among engineers, especially in the power field, there still appears to be some confusion as to the purpose and functions of the National Bureau of Engineering Registration which has its headquarters at Columbia, S. C.

This bureau is conducted by the National Council of State Boards of Engineering Examiners, assisted by an advisory committee representing seven national engineering societies. Its purpose is to serve as a clearing house for information concerning the professional records of engineers and to assist engineers practicing in more than one state to minimize the effort and expense of securing registration.

It does not issue licenses to practice professional engineering (this is the prerogative of the State Boards) but the professional record of an applicant is investigated, his references consulted, and, if all requirements are met, a Certificate of Qualification is issued. Such a certificate serves as evidence of qualification for registration with State Boards, for membership in engineering societies, for presentation to clients when soliciting contracts for professional services and for presentation to prospective employers. The registration laws of some states specifically provide for the acceptance of these certificates, whereas other states require additional examinations in certain subjects.

Briefly, the minimum requirements for a Certificate of Qualification are as follows:

A. Graduation from an approved course in engineering of four years or more in a school or college approved by the Bureau; and a specific record of an additional four years or more of active practice in engineering work indicating that the applicant is competent to be placed in responsible charge of important engineering work; or

B. Successfully passing a written, or written and oral examination designed to show knowledge and skill approximating that attained through graduation from an approved four-year engineering course; and a specific record of eight years or more of active practice in engineering work indicating that the applicant is competent to be placed in responsible charge of important engineering work; or

C. A specific record of twelve years or more of active practice in engineering work of a character satisfactory to the Bureau and indicating that the applicant is qualified to design or to supervise construction of engineering works and has had responsible charge of important engineering work for at least five years and provided applicant is not less than thirty-five years of age.

A fee of $10 is charged for investigating and verifying the professional record of an applicant and $5 additional for the certificate.

Worthington Elects New Director—The election of A. G. Pratt, President of The Babcock & Wilcox Company, to the Board of Directors of the Worthington Pump and Machinery Corporation, is announced.

EQUIPMENT SALES

Boiler, Stoker, Pulverized Fuel

As reported by equipment manufacturers of the Department of Commerce, Bureau of the Census.

Boiler Sales

Orders for 56 water-tube and h.r.t. boilers were placed in December

	Number	Square Feet
December, 1933	56	166,293
December, 1932	31	92,983
January to December (inclusive, 1933)	944	2,871,913
Same period, 1932	641	2,124,361

NEW ORDERS, BY KIND, PLACED IN DECEMBER, 1932–1933

	December, 1932		December, 1933	
Kind	Number	Square Feet	Number	Square Feet
Stationary:				
Water tube	16	77,988	37	143,261
Horizontal return tubular	15	14,995	19	23,032
	31	92,983	56	166,293

Mechanical Stoker Sales

Orders for 113 stokers, Class 4,* totaling 17,967 hp. were placed in December by 42 manufacturers.

	Installed under			
	Fire-tube Boilers		Water-tube Boilers	
	No.	Horsepower	No.	Horsepower
December, 1933	100	13,742	13	4,225
December, 1932	78	11,774	20	6,601
January to December (inclusive, 1933)	1,136	144,099	409	149,928
Same period, 1932	920	122,346	367	139,173

* Capacity over 300 lb. of coal per hr.

Pulverized Fuel Equipment Sales

Orders for 8 pulverizers with a total capacity of 67,500 lb per hr. were placed in December

STORAGE SYSTEM

	Pulverizers				Water-tube Boilers		
	Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
December, 1933	..	..	..	....	..	....	......
December, 1932	..	..	..	....	..	....	......
January to December (inclusive, 1933)	6	4	2	220,000	4	109,432	1,445,000
Same period, 1932	..	..	..	....	..	....	......

DIRECT FIRED OR UNIT SYSTEM

	Pulverizers				Water-tube Boilers		
December, 1933	8	4	4	67,500	5	53,200	653,000
December, 1932	..	..	..	....	..	......	....
January to December (inclusive, 1933)	107	74	33	700,240	81	591,977	5,979,810
Same period, 1932	73	48	25	392,888	64	463,194	3,536,260
					Fire-tube Boilers		
December, 1933	..	..	..	....	..	....	......
December, 1932	..	..	..	....	..	....	......
January to December (inclusive, 1933)	17	3	14	19,450	18	27,610	170,940
Same period, 1932	13	2	11	13,300	13	20,310	114,650

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